# DRAFT GUIDANCE FOR HAZARD DETERMINATION

## FOR COMPLIANCE WITH THE OSHA HAZARD COMMUNICATION STANDARD (29 CFR 1910.1200)

**U.S. Department of Labor**

**Occupational Safety and Health Administration**

## TABLE OF CONTENTS

## OVERVIEW

This document is designed to help manufacturers and importers of chemicals identify chemical hazards so that employees and downstream users can be informed about these hazards, as required by the Occupational Safety and Health Administration's (OSHA) Hazard Communication Standard. This guidance may also be useful to employers who decide to conduct hazard determinations in order to assure the accuracy and completeness of information provided to them by suppliers. Hazard determination is the critically important first stage in the process of establishing an effective hazard communication program.

The process of hazard determination consists of four basic steps. These are:

- Selection of chemicals to evaluate;
- Collection of data;
- Analysis of the collected data; and
- Documentation of the hazard determination process and the results obtained.

The intent of this document is to provide guidance as to the processes involved and to identify considerations in the conduct of hazard determinations. Since much of the discussion is of a technical nature, a Glossary of Terms and Definitions is included as Appendix A.

This guidance document provides a description of the hazard determination process. This document does not itself alter or determine compliance responsibilities, which are set forth in the Hazard Communication Standard (29 CFR 1910.1200) and in the Occupational Safety and Health Act. Moreover, because interpretations and enforcement policy may change over time, the reader should consult current administrative interpretations and decisions by the Occupational Safety and Health Review Commission and the courts for additional guidance on OSHA compliance requirements.

## INTRODUCTION

OSHA's Hazard Communication Standard (HCS) is designed to protect against chemical source illnesses and injuries by ensuring that employers and employees are provided with sufficient information to recognize chemical hazards and take appropriate protective measures. This information is provided through material safety data sheets (MSDSs), labels, and worker training. In order for MSDSs, labels, and training to be effective, the hazard information they convey must be complete and accurate. Thus it is critically important to obtain comprehensive and correct information about the hazards associated with particular chemicals.

### What is Hazard Determination?

Hazard determination is the process of evaluating available scientific evidence in order to determine if a chemical is hazardous. This evaluation identifies both physical hazards (e.g., flammability or reactivity) and health hazards (e.g., carcinogenicity or sensitization). The hazard determination provides the basis for the hazard information that is provided in MSDSs, labels, and worker training.

Hazard determination does not involve an estimation of risk. The difference between the terms hazard and risk has often been poorly understood. Hazard refers to an inherent property of a substance that is capable of causing an adverse effect. Risk, on the other hand, refers to the probability that an adverse effect will occur with specific exposure conditions. Thus a substance will present the same hazard in all situations due to its innate chemical or physical properties and its actions on cells and tissues. However, considerable differences may exist in the risk posed by a substance, depending on how the substance is contained or handled, personal protective measures used, and other conditions that result in or limit exposure. This document addresses only the hazard determination process, and will not discuss risk assessment.

### Who Must Conduct Hazard Determinations?

Only chemical manufacturers and importers are required to perform hazard determinations on the chemicals they produce or import. Under the HCS, an employer that manufactures, processes, formulates, or repackages a hazardous chemical is considered a

"chemical manufacturer." Distributors and employers may also choose to conduct hazard determinations if they are concerned about the adequacy of hazard information for the chemicals they use in their business or distribute to others.

Regardless of who performs the hazard determination, the procedures used must be described in writing and made available, upon request, to employees and their designated representatives, as well as OSHA and National Institute for Occupational Safety and Health (NIOSH) officials.

## What Resources are Needed to Conduct a Hazard Determination?

Two primary resources are required for hazard determination. First is complete and accurate literature and data concerning the chemical in question. Second is the ability to properly understand and interpret the information retrieved in order to identify and document hazards. Manufacturers and importers of hazardous chemicals are responsible for ensuring that hazard information provided to their employees and downstream users is complete and accurate. To achieve this, the persons assigned to conduct hazard determinations must have the ability to conduct complete and effective literature and data retrieval. They should also be able to interpret the literature and data in order to determine the nature and extent of physical and health hazards. A lack of qualified employees does not exempt a manufacturer or importer from compliance with the HCS.

## How Should This Guidance Document be Used?

The hazard determination requirements of the HCS are performance oriented. That is, chemical manufacturers, importers, and employers evaluating chemicals are not required to follow any specific procedures for determining hazards, but they must be able to demonstrate that they have adequately ascertained the hazards of the chemicals produced or imported in accordance with the criteria set forth in the HCS.

This guidance document will not provide detailed methods that must be followed. However, a basic framework for hazard determination is provided, along with a description of a process that can be used to conform to the requirements of the HCS. The interpretation of information relating to the physical and health hazards associated with a chemical can be a highly technical undertaking, and is often conducted by experienced toxicologists

and industrial hygienists. This document will not replace the need for such professional expertise in certain situations. It is intended to serve only as useful guidance as to the basic considerations and operational aspects involved in the conduct of hazard determinations.

## THE HAZARD DETERMINATION PROCESS

### What is the HCS Definition of "Chemical"?

The definition of chemical in the HCS is much broader than that which is commonly used. The HCS definition of chemical is "any element, chemical compound, or mixture of elements and/or compounds." Thus virtually any product is a "chemical." These various types of chemicals are as follows:

- ***Element*** - the simplest form of matter. There are currently 109 known elements in the periodic table. Examples of elements are aluminum, carbon, chlorine, hydrogen, mercury and oxygen.
- ***Chemical compound*** - a substance consisting of two or more elements combined or bonded together so that its constituent elements are always present in the same proportions.
- ***Mixture*** – any combination of two or more chemicals if the combination is not, in whole or in part, the result of a chemical reaction.

Although virtually all materials are considered chemicals under this definition, the HCS identifies certain categories of chemicals that are not covered by the standard. These categories are:

Any **hazardous waste** as defined by the Solid Waste Disposal Act when subject to regulations issued under that Act by the Environmental Protection Agency;

Any **hazardous substance** as defined by the Comprehensive Environmental Response, Compensation and Liability Act **when the hazardous substance is the focus of remedial or removal action** being conducted under that Act in accordance with Environmental Protection Agency regulations;

**Tobacco or tobacco products**;

**Wood or wood products**, including lumber which will not be processed, where the chemical manufacturer or importer can establish that the only hazard they pose to employees is the potential for flammability or combustibility (wood or wood products which have been treated with a hazardous chemical covered by this standard, and wood which may be subsequently sawed or cut, generating dust, are not exempted);

**Articles**, defined as a manufactured item other than a fluid or particle: (i) which is formed to a specific shape or design during manufacture; (ii) which has end use function(s) dependent in whole

or in part upon its shape or design during end use; and (iii) which under normal conditions of use does not release more than very small quantities, e.g., minute or trace amounts of a hazardous chemical, and does not pose a physical hazard or health risk to employees.

**Food or alcoholic beverages** which are sold, used, or prepared in a retail establishment (such as a grocery store, restaurant, or drinking place), and foods intended for personal consumption by employees while in the workplace;

Any **drug**, as that term is defined in the Federal Food, Drug, and Cosmetic Act, when it is in solid, final form for direct administration to the patient (e.g., tablets or pills); drugs which are packaged by the chemical manufacturer for sale to consumers in a retail establishment (e.g., over-the-counter drugs); and drugs intended for personal consumption by employees while in the workplace (e.g., first aid supplies);

**Cosmetics** which are packaged for sale to consumers in a retail establishment, and cosmetics intended for personal consumption by employees while in the workplace;

Any **consumer product** or **hazardous substance**, as those terms are defined in the Consumer Product Safety Act and Federal Hazardous Substances Act, respectively, where the employer can show that it is used in the workplace for the purpose intended by the chemical manufacturer or importer of the product, and the use results in **a duration and frequency of exposure which is not greater than the range of exposures that could reasonably be experienced by consumers when used for the purpose intended**;

**Nuisance particulates** where the chemical manufacturer or importer can establish that they do not pose any physical or health hazard covered under this section;

**Ionizing and nonionizing radiation**; and

**Biological hazards**.

## How Will I Know if My Chemical is "Hazardous"?

Under the HCS, any chemical that is a physical hazard or a health hazard is considered a hazardous chemical. The HCS definitions for physical and health hazards are:

- ***Physical hazard*** means a chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive) or water-reactive.
- ***Health hazard*** means a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occu in exposed employees. The term "health hazard" includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic system, and agents which damage the lungs skin, eyes, or mucous membranes. [ ]

These different types of hazards identified in the HCS are presented in Table 1.

Table 1. HCS Listed Hazard Categories

| Physical Hazards | Health Hazards |
|---|---|
| Fire Hazards | Systemic Effects |
| Combustible liquid | Carcinogen |
| Flammable liquid | Toxic agent |
| Flammable aerosol | Highly toxic agent |
| Flammable gas | Corrosive |
| Flammable solid | Irritant |
| Oxidizer | Sensitizer |
| Pyrophoric | |
| | Target Organ Effects |
| Explosion Hazards | Hepatotoxin |
| Compressed gas | Nephrotoxin |
| Explosive | Neurotoxin |
| | Blood/hematopoietic toxin |
| Reactive Hazards | Respiratory toxin |
| Organic peroxide | Reproductive toxin |
| Unstable (reactive) | Cutaneous hazard |
| Water-reactive | Eye hazard |

For a hazard determination to be complete, one must consider all possible hazards, and document any hazards that are identified. While the hazards listed in the HCS represent the majority of potential workplace hazards, the list is not all-inclusive, especially for health hazards. Table 2 is a list of important health hazards that should be evaluated in addition to those specifically listed by HCS.

In conducting the hazard determination, one should be aware of all types of physical and health hazards.

Table 2. Other Important Health Hazards

| | |
|---|---|
| Cardiovascular toxicity | Gastrointestinal toxicity |
| Immunotoxicity | Skeletal/muscular effects |
| Connective tissue effects | Endocrine system toxicity |
| Sensory organ toxicity (sight, hearing, taste) | |

Certain chemicals are specifically designated as hazardous by the HCS. The HCS listing of hazardous chemicals has been referred to as the "floor" from which other hazardous chemicals should be added. The HCS base list of hazardous chemicals are provided in the following references:

- OSHA Toxic and Hazardous Substances, 29 CFR part 1910, Subpart Z (see Appendix C);
- Threshold Limit Values for Chemical Substances and Physical Agents (American Conference of Governmental Industrial Hygienists, latest edition); or

Carcinogens or potential carcinogens according to one or more of the following sources:

- 29 CFR part 1910, Subpart Z, Toxic and Hazardous Substances (OSHA) (see Appendix D);
- National Toxicology Program Annual Report on Carcinogens, latest edition (see Appendix E);
- International Agency for Research on Cancer Monographs, latest editions (see Appendix F).

The definition for hazardous chemical in the standard is thus very broad, and it is not likely that many chemicals will be considered as non-hazardous if they have been adequately tested. However, the standard does not require the testing of chemicals - only the collection and analysis of currently available data. Testing should be considered if hazardous properties are suspected.

## Is Hazard Determination the Same for Mixtures as for Individual Elements and Compounds?

Generally speaking, the chemical and physical properties and hazards of pure elements and chemical compounds are precise and constant. For example, benzene has explicit boiling and flashpoints of 1760 F and 120 F (at sea level), respectively. In contrast, the properties of the complex mixture, Stoddard Solvent, can vary considerably depending on the manufacturer and lot received, with ranges for boiling and flash points of 309-3960 F and 102-1100 F, respectively.

The process for evaluating mixtures may require additional steps in addition to those indicated for single chemical agents. The HCS has designated specific requirements for mixtures. These requirements depend upon the availability of test data as indicated below:

- If a mixture has been tested as a whole, the results should be used to determine whether the mixture is hazardous.
- If a mixture has not been tested as a whole for health hazards, the mixture shall be assumed to present the name hazards as components of 1.0 percent (1%) or greater of the mixture. An exception pertains to carcinogens. In this case, the mixture shall be assumed to present a carcinogenic hazard if it contains a carcinogenic component of 0.1 percent (0.1%) or greater.
- If a mixture has not been tested as a whole to determine whether the mixture is a physical hazard, the chemical manufacturer or importer may use whatever scientifically valid data is available to evaluate the physical hazards of the mixture.
- If there is evidence that a component is present at less than one percent (< 0.1% for carcinogens) and could be released into the workplace environment in concentrations that would exceed an OSHA PEL or ACGIH TLV, or present a health hazard in those concentrations, the mixture is assumed to present the same hazard.

## What is Involved in the Conduct of a Hazard Determination?

All possible physical or health hazards that might be associated with a chemical's use must be considered. The hazard determination process consists of four main steps:

- Selection of chemicals to evaluate;
- Collection of data;
- Analysis of the collected data; and
- Documentation of the hazard determination process and the results obtained.

Written procedures generally describe the process followed; they do not have to address, individually, each chemical evaluated. If no hazards are found, the manufacturer, importer, or employer is not required to take further action pertaining to the evaluated chemical. Even if no hazards are found, however, documentation of the steps taken to evaluate the chemical (and any retrieved data) may be useful for future reference.

For most of the chemicals specifically designated as hazardous in the HCS, the available information has been compiled in readily available and reliable sources (see Appendix B). If a chemical is not specifically designated as hazardous, you must collect and evaluate the data and determine if the chemical is hazardous. The hazard determination for these chemicals may be more involved since reliable data compilations may not exist. The determination in this case requires a more exhaustive search for information.

In some cases, a chemical may possess a single hazard. In other cases, several hazards may be associated with exposure to a chemical. Hazards range from mild to severe. For example, the identified hazard for acetic acid, as normally used in industry, is irritation (sensory and respiratory). In contrast, exposure to lead may involve several health hazards, including neurotoxicity, blood effects, cardiovascular damage, kidney damage, and birth defects.

The hazard evaluation is a process that relies heavily on the judgment of the evaluator, particularly in the area of chronic hazards. The performance-orientation of the HCS does not diminish the duty of the chemical manufacturer, importer or employer to conduct a thorough evaluation, examining all relevant data and producing a scientifically defensible evaluation.

## SELECTION OF CHEMICALS

The ultimate goal in the hazard determination process is to know and document the hazards of all covered chemicals you manufacture or import. In order to achieve this you must first determine which chemicals require a hazard determination. The logical way to do this is to first prepare an inventory of all chemicals manufactured or imported. Items exempted from coverage under the HCS may be excluded from the inventory. For chemicals obtained from suppliers, you may rely upon the MSDSs and labels provided by the chemical manufacturer or importer. However, you may choose to conduct hazard determinations for those chemicals if you are concerned about the adequacy of the hazard information you have received.

***First Step***
**Prepare a chemical inventory**

The inventory should anticipate the full range of downstream uses of the products and account for any hazardous by-products which may be formed. For example, a manufacturer of gasoline must inform downstream users of the hazards of carbon monoxide, since carbon monoxide is a hazardous chemical and is "known to be present" as a by-product resulting from the use of gasoline. Similarly, manufacturers of diesel must inform downstream users of the potential human carcinogenicity of diesel exhaust on the MSDSs for diesel fuel.

If an inventory is not already in place, a good start could be to review purchase orders to create an initial inventory. Next, one should conduct an inspection of all areas noting any additional chemicals present that should supplement the initial inventory. It would be ideal to note the location and quantity of each chemical found. Chemical inventories are often maintained as computer files for ease and efficiency in keeping them current. With knowledge of the chemicals in your possession, hazard determinations can now be performed for chemicals in the inventory.

## DATA COLLECTION

**What data should be collected?**

**Where can I find the data?**

The second step in the hazard determination process is data collection. There are two main questions to be answered: 1) what type of data should be searched for and collected; and 2) how do I go about finding sources that might contain the desired data? You should recognize that the hazard determination process involves the identification of all of the hazards associated with a chemical, not just some of them. This process must be completed even though some data elements may be difficult to locate. Any hazard that exists for the chemical must be identified and communicated to downstream employers and employees.

To complete the hazard identification, information is needed in three categories:

- chemical identity;
- chemical and physical properties; and
- health effects.

There are numerous sources that could be searched for this information. A first step is to consult primary sources of information such as those listed in Appendix B. These sources have compiled data pertaining to many chemicals and are considered generally reliable. If that search fails to provide the needed data for your chemical, you may need to search secondary or computerized literature sources. A number of these additional sources are also listed in Appendix B. For new or less commonly used chemicals, there may not be data available in any of these sources. In such cases, you may choose to test the chemical to determine chemical and physical properties and identify hazards.

In the sections that follow, a discussion of data needs for the three categories of information is provided. Also, a few recommended key references for the various types of data are listed. You should recognize that complete and reliable data must be entered on MSDSs and labels in order to meet HCS requirements. Before the search for hazard data can begin, however, you must identify the exact chemical composition of the chemical(s) or products manufactured or imported. For mixtures or products, this chemical search includes the name of each chemical in the mixture, including active ingredients, inactive ingredients, and impurities.

The specific chemical identity of all chemicals on your Chemical Inventory should be carefully and completely compiled. The specific chemical identity should include:

- the chemical name along with common name and synonyms;
- the Chemical Abstracts Services (CAS) Registry Number (if available); and
- any other information that reveals the precise chemical designation and composition of the substance.

An example of the type of chemical identification data needed is presented for Perclene®, a widely used industrial solvent. Perclean® is a trade name for perchloroethylene or Perc (common name), or more specifically tetrachloroethylene (the actual chemical name (CAS Number 127-18-4). To avoid confusion, literature is often indexed using the CAS number or the primary chemical name. Thus, the most effective search of computerized databases is conducted using tetrachloroethylene and/or CAS Number 127-18-4. Several databases exist that can be searched for the CAS number or chemical name if one only has a trade or common name. Another problem with the use of common names is that they may be used for more than one substance. TCE is sometimes used as an acronym for tetrachloroethylene, although it more frequently refers to trichloroethylene. Use of the exact chemical name or CAS number avoids confusion and erroneous data retrieval. The CAS number is unique for each chemical and should be used, along with the chemical name, when searching computerized databases for information on a specific chemical.

**Correct identification of chemicals is critical for data retrieval. Use the precise chemical name and CAS number when searching for information.**

The percent composition should be available in-house for all chemicals and products manufactured or imported. The chemical composition information should be based on an analysis of the final or technical product. A technical grade product is not usually a pure substance and often contains other chemicals such as stabilizers, solvents, carriers, “inert” ingredients, or impurities. For the hazard evaluation process, these other chemicals must also be examined if they are more than 1.0% of the composition for non-carcinogenic substances or 0.1% of the product if the substance is a carcinogen.

Thus, the initial step is to collect as much data as possible pertaining to the physical and chemical properties and toxicity data for chemicals on your chemical inventory.

Key sources of information related to chemical identification are:

- Company Records;
- MSDSs and product safety bulletins from manufacturers or suppliers;
- OSHA Chemical Information Manual/Database; The Merck Index; ChemID; and
- Trade Associations.

## Physical and Chemical Properties

The physical properties of a substance can be directly related to the probability of the substance representing a physical hazard. However, the fact that a substance has a certain physical property cannot necessarily be used to predict a physical hazard. For example, all volatile substances are not necessarily explosive. Some solids can also be explosive (e.g., TNT or grain dust particles). Nevertheless, knowing the physical properties does have great value in predicting whether a substance may be a physical hazard.

**A chemical may possess more than one physical or health hazard.**

Key sources of information related to physical and chemical properties include:

- NFPA Fire Protection Guide to Hazardous Materials;
- Department of Transportation 2000 Emergency Response Guidebook;
- Hazardous Substances Data Bank (HSDB);
- Product safety bulletins from manufacturers or suppliers;
- The Merck Index;
- NIOSH Pocket Guide to Chemical Hazards;
- CRC Handbook of Chemistry and Physics;
- Bretherick's Handbook of Reactive Chemicals Hazards; and
- Trade Associations.

## Health Effects

The HCS includes a list of 14 potential health hazards, as well as criteria for determining when a chemical represents a health hazard. In many cases, a chemical may pose more than one type of health hazard. If your company manufactures a new chemical you may be required to submit premanufacture health effects data to the EPA to comply with the Toxic Substances Control Act (TSCA). Data submitted by other companies may be available from the EPA. This data should be used to assist with hazard determination. For chemicals that have not been studied in-house or via company-sponsored contract toxicology studies, the company should seek toxicity data from the literature, government, or private sources. Key sources of information related to health hazards are:

**All potential health hazards must be determined - not just those identified by OSHA**

- Company-sponsored research;

- Product safety bulletins from manufacturers or suppliers;
- Hazardous Substances Data Bank (HSDB);
- Registry of Toxic Effects of Chemical Substances (RTECS®);
- NIOSH Pocket Guide to Chemical Hazards;
- OSHA Chemical Information Manual/Database;
- IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to man;
- NTP Annual Report on Carcinogens;
- ACGIH TLVs and BEIs;
- Hawley's Condensed Chemical Dictionary, 14th Edition;
- Sax's Dangerous Properties of Industrial Materials, 10th Edition;
- Published Literature; and
- Trade Associations.

## DATA ANALYSIS

The third step in the hazard determination process is data analysis. This step is the most demanding in technical expertise. The HCS requires that chemical manufacturers and importers conduct a hazard determination to determine whether physical or health hazards exist. In some cases, especially for physical hazards, a definition in the HCS establishes the criteria to be followed. For example, if a liquid has a flash point below $100^0$ F, it is by definition a "flammable liquid". This type of procedure is a simple data analysis. You can look up the flash point in a standard reference and accept it at face value. In the event your company is manufacturing or importing a chemical for which there is no information on the flash point, you may choose to determine the flash point by laboratory testing, but testing is not required by the HCS.

As a rule, the HCS attempts to minimize the burden of literature search and review while satisfying the need to provide information required to protect employees who are exposed to hazardous chemicals. For this reason, a suggested approach is to go to the most likely sources first to obtain the needed data, and then proceed to additional sources if necessary.

For health hazards, explicit criteria are provided in the HCS for some health hazards. For example, criteria are given for classifying a chemical as highly toxic or toxic based on acute effects, and for designating a chemical as a carcinogen. For other health hazards, a simple generic requirement is provided for the determination of a specific health hazard. The HCS states that "evidence that is statistically significant and which is based on at least one positive study conducted in accordance with established scientific principles is considered to be sufficient to establish a hazardous effect if the results of the study meet the [HCS] definitions of health hazards."

Let's examine this requirement further. There are three key criteria that must be met, namely "statistically significant", "positive study", and "established scientific principles". Thus, the evaluation of study results requires some knowledge of statistics, commonly accepted scientific test methodology, and the definitions of health hazards.

Statistical significance is a mathematical determination of the confidence in the outcome of a test. The usual criterion for establishing statistical significance is the p-value (probability value). A statistically significant difference in results is generally indicated by $p<0.05$. By $p<0.05$, there is less than 5% probability that the toxic effects observed were due to chance and were not caused by

the chemical. Another way of looking at it is that there is a 95% probability that the effect is real, i.e., the effect seen was the result of the chemical exposure.

The other major indication of statistical significance is the 95% confidence level for a specific data point. Most reports of toxicity testing will include some information on the confidence in the data. For example, an $LD_{50}$ with a listed value of $9.5 \pm 1.2$ indicates that if the same study were to be repeated many times, the $LD_{50}$ would be expected to be within the range of 8.3 - 10.7 on 95 out of every 100 times.

Most toxicity and epidemiology reports will provide an analysis of the data and conclude whether the results were positive or negative, or will describe the adverse effects observed at specific dose levels. By positive, this means that the exposed humans or animals were more likely to develop toxic effects than the non-exposed population. Normally, the investigator's statistical analysis and conclusions can be accepted.

Hazard evaluation relies on professional judgment, particularly in the area of chronic hazards. The performance-orientation of the HCS does not diminish the duty of the chemical manufacturer, importer or employer to conduct a thorough evaluation, examining all relevant data and producing a scientifically defensible determination.

In the remainder of this section, an overview is presented of the HCS designated hazards and their definitions. In addition, a brief discussion is presented to further explain the specific hazard and procedures that can be used to analyze the data. Because this document can only present a limited discussion of the various hazards, you are encouraged to consult references that go into greater detail (see Appendix B of this document).

## Physical Hazards

A chemical is a physical hazard if it:

- is likely to burn or support fire;
- may explode or release high pressures that can inflict body injury; or
- can spontaneously react on its own, or when exposed to water.

### *Fire Hazards*

### *Combustible and Flammable Liquids*

**Flashpoint is the primary measure of a liquid chemical's propensity to burn**.

The ability of a chemical to either burn or support burning is a potentially disastrous physical hazard. The two primary measures of the ease with which a liquid will burn are the flashpoint and auto-ignition temperature. The flashpoint is the lowest temperature at which a liquid will emit sufficient vapors to form an ignitable mixture with air. In contrast, auto-ignition is the characteristic of a material in which it will spontaneously burn without the aid of an ignition source, such as a spark or flame. Many agents will burn when ignited whereas there are only a few that will spontaneously erupt into flames. While no single measure of flammability is sufficient for all purposes, the most commonly found measure in the literature is the flashpoint. For this reason, HCS uses flashpoint in classifying the fire hazard of a chemical.

Flammable liquids and combustible liquids are discussed together since flashpoint is the criteria for classification of both. The only difference between a "flammable" and "combustible" liquid is the relative ease (temperature) with which the substance burns or supports burning. The data analysis and hazard categorization are clear. For a pure chemical compound, the assignment to combustible or flammable liquid categories is quite simple:

- if the flashpoint is between $100^0$F - $200^0$F ($37.8^o$C - $93.3^0$C), it is a combustible liquid;
- if the flashpoint is below $100^o$F ($38^o$C), it is a flammable liquid.

The HCS definition for combustible liquid is "any liquid having a flash point between $100^o$F ($37.8^o$C) and $200^o$ F ($93.3^o$C), except any mixture having components with flashpoints of $200^o$F ($93.3^o$ C) or higher, the total volume of which makes up 99 percent or more of the total volume of the mixture."

The HCS definition for flammable liquid is "any liquid having a flash point below $100^o$F ($38^o$C), except any mixture having components with flashpoints of $100^o$F ($38^o$C) or higher, the total of which make up 99 percent or more of the total volume of the mixture."

You see that HCS has made exceptions for chemical mixtures. A mixture will not be categorized as a combustible liquid so long as less than 1% of the total volume of components have flashpoints between $100^o$ and $200^o$ F. For example, if Chemical A has a flashpoint of $180^0$ F and represents 0.5% of the mixture and all other chemicals have flashpoints above $200^0$ F, then the mixture is not considered a combustible liquid. Similarly, a mixture will not be categorized as a flammable liquid if it is composed of at least 99% (by volume) of components with flash points above $100^o$F ($38^o$C). Many mixtures will contain more than 1% of a flammable liquid and

the mixture will have a flash point above 100°F. Where data indicating the flashpoint of a chemical is not available, you may choose to test the chemical to determine the flashpoint.

When a substance flashes, the resulting flame will spread through the vapor from the ignition source to the nearby surface of the liquid. From a practical viewpoint, a flammable liquid is potentially more hazardous than a combustible liquid. A flammable liquid presents a fire hazard if present in an open container near an ignition source in an environment in which the temperature is at or below normal room temperature. Examples of flammable liquids (with flash point temperatures) are: acetone ($0^0$F), ethyl ether ($-49^0$ F), ethyl alcohol ($55^0$ F), and gasoline ($-45^0$ F). For a combustible liquid to present a fire hazard it must be above normal room temperature. Examples of combustible liquids are kerosene ($100^0$-$162^0$F) and Stoddard solvent ($102^0$-$110^0$F).

### *Flammable Aerosol*

The HCS definition for flammable aerosol is "an aerosol that, when tested by the method described in 16 CFR 1500.45, yields a flame projection exceeding 18 inches at full valve opening, or a flashback (a flame extending back to the valve) at any degree of valve opening."

The analysis as to whether the chemical is a flammable aerosol is more difficult and usually must be based upon laboratory testing of the aerosol as emitted from a pressurized container. In practice, most aerosols are mixtures, usually in air, and are primarily propellant formulations of droplets, particles, gases, and/or vapors. Their flammability is highly dependent on the nature of the propellant formulation. Unless data obtained from a literature search pertains to the exact mixture of ingredients in the product, the data may not be accurate. In the event that you choose to test a chemical product to determine if it is a flammable aerosol, the method described in 16 CFR 1500.45 should be used. A positive test is obtained if a flame is projected at least 18 inches at full valve opening, or if there is a flashback (i.e., a flame extends back to the valve) at any degree of valve opening.

### *Flammable Gas*

The HCS definition for flammable gas is "a gas that, at ambient temperatures and pressures, forms a flammable mixture with air at a concentration of less than thirteen (13) percent by volume; or forms a range of flammable mixtures with air wider than twelve (12) percent by volume."

Thus, a gas can be categorized as flammable if the gas:

- burns in air at a concentration of less than 13%; or
- has a lower flammability limit (LFL) of 13% or more with a concentration range for burning in air greater than 12%. The range is the difference between the LFL and the upper flammability limit (UFL).

The LFL is the minimal concentration of vapor below which combustion will not occur even in the presence of an external ignition source, whereas the UFL is the maximum vapor concentration above which combustion cannot take place. To understand the concept, that at a certain concentration a gas will burn whereas it will not if the concentration is too low or too high, consider the carburetor of an automobile. The carburetor must be correctly adjusted so that the gasoline/air mixture is not too lean or too rich, or the gasoline/air vapor mixture will not burn in the automobile engine. Gasoline has an LFL of 1.4% and an UFL of 7.6%.

Methane and butane are examples of flammable gases that burn at less than 13% concentration in air. Acetone is an example of a flammable liquid that volatilizes but does not represent a flammable gas. This is true because the LFL is 16% and the UFL is 25%, which is a difference of only 9% (the definition requires a difference of at least 12%). On the other hand, ammonia is categorized as flammable since it has a LFL of 15% and an UFL of 28%, a difference of 13%.

***Flammable Solid***

The HCS definition of a flammable solid is "a solid, other than a blasting agent or explosive as defined in [29 CFR] 1910.109(a), that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious hazard. A chemical shall be considered a flammable solid if, when tested by the method described in 16 CFR 1500.44, it ignites and burns with a self-sustained flame at a rate greater than one tenth of an inch per second along its major axis."

The analysis as to whether a solid chemical will burn with such intensity to be classified as a flammable solid usually must be based upon the results of laboratory testing. If you choose to test a chemical to determine if it is a flammable solid, such testing should be conducted by the method described in 16 CFR 1500.44. A flammable solid can be ignited readily and then will burn so vigorously as to create a serious fire hazard. Blasting agents or explosives may be solids that burn but with an intensity so great that they are classified as explosives. An example of a flammable

solid that can be ignited by friction is the chemical formulation on the head of matches. Some metal powders (such as magnesium) can react with moisture and burn and are thus classified as flammable solids.

### *Oxidizer*

The HCS classifies a chemical as an oxidizer if it is a "chemical other than a blasting agent or explosive as defined in [29 CFR] 1910.109(a), that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases."

An oxidizing agent is a chemical or substance that brings about an oxidation reaction. The agent may provide the oxygen to the substance being oxidized (in which case the agent has to be oxygen or contain oxygen), or it may receive electrons being transferred from the substance undergoing oxidation (e.g., chlorine is a good oxidizing agent for electron-transfer purposes, even though it contains no oxygen).

Oxidizing materials can initiate or greatly accelerate the burning of fuels. The most common oxidizer is atmospheric oxygen. Oxygen-containing chemicals (e.g., hydrogen peroxide and nitrous oxide) and halogens (e.g., bromine, chlorine, and fluorine) can also be strong oxidizers. Some chemicals may be oxidizers with such an extremely fast burning potential that they are classified as explosives or blasting agents rather than oxidizers. Often the fact that a chemical possesses oxidizing potential can be obtained from an examination of its chemical structure. For example, oxidizing substances usually include recognizable functional chemical groups, e.g., perchlorate ($ClO_4^-$), chlorate ($ClO_3^-$), chlorite ($ClO_2^-$), hypochlorite ($ClO^-$), peroxide ($-O-O-^{=}$), nitrate ($NO_3^-$), nitrite ($NO_2^-$), dichromate ($Cr_2O_7^{=}$), persulfate ($S_2O_8^{=}$), and permanganate ($MnO_4^-$).

While the potential for oxidizing can often be inferred by chemical structure, absolute certainty can only be properly verified in the laboratory since oxidation involves not only the oxidizing potential of the oxidizer, but also the chemical formulation of the fuel to which it comes in contact. Oxidizers are classified by comparison with the oxidizing properties of a standard test chemical, ammonium persulfate, applied to dry, conditioned sawdust. A solid that promotes combustion of the conditioned sawdust at a greater rate than ammonium persulfate is classified as an oxidizer.

### *Pyrophoric Hazards*

The HCS definition for a pyrophoric chemical is "a chemical that will ignite spontaneously in air at a temperature of $130^0$ F ($54.4^0$ C) or below." Fortunately, there are only a few chemicals that have the ability to catch fire without an ignition source when exposed to air. Many of these are elements (e.g., lithium, powdered aluminum, magnesium) or organometallic compounds (such as lithium hydride, diethyl zinc and arsine). Moisture in the air often increases the probability of spontaneous ignition of pyrophoric materials.

## *Explosive Hazards*

### *Compressed Gas*

The HCS definition for Compressed Gas is:

> (i) "a gas or mixture of gases having, in a container, an absolute pressure exceeding 40 psi at $70^0$ F ($21.1^0$ C): or
> (ii) a gas or mixture of gases having, in a container, an absolute pressure exceeding 104 psi at $130^0$ F ($54.4^0$ C) regardless of the pressure at $70^0$ F ($21.1^0$ C); or
> (iii) a liquid having a vapor pressure exceeding 40 psi at $100^0$F ($37.8^0$ C) as determined by ASTM D-323-72."

All compressed gases are potentially hazardous since they are under great pressure in a container. Accidental rupture of the container and the rapid release of the pressurized gas can result in injury to persons and damage to objects in the vicinity. Not only can the gas be released with great force, but the force of the release may propel the container for a long distance. In addition to the mechanical hazard from the pressure or propelled container, other hazards may exist from the released gas. The hazard from some compressed gases may be strictly mechanical (e.g., compressed air and nitrogen), others may possess other types of hazards, such as being flammable (e.g., methane and propane) or toxic (e.g., ammonia and chlorine).

### *Explosive*

The HCS definition for explosive is "a chemical that causes a sudden, almost instantaneous release of pressure, gas, and heat when subjected to sudden shock, pressure, or high temperature."

Explosives are unstable materials and are of two types. One type consists of material capable of supersonic reactions (detonation), for example, nitroglycerine and TNT. The other type consists of materials (usually mixtures) that burn rapidly but at a subsonic rate.

Examples of this type are gunpowder, rocket propellants, and pyrotechnic mixtures (fireworks). The difference between fire and explosion is the rate at which high temperature gases are produced and the physical containment of the burning gases. When high temperature gases build up extremely fast, there can be such a sudden release of energy from the gases that a shock wave or explosion is created. Confining the build-up of high pressure gases in a drum or vessel, which prevents venting of the gases, may promote an increase in the pressure within the restricted volume until an explosion occurs. Such is the principle behind some munitions, which confine high pressure gases until the pressure exceeds the strength of the casing.

Most explosives have a chemical structure that contains both oxidizing and fuel functional groups. Examples of functional groups contained in explosives are: azides, dizonium, and styphnate. While the presence of such functional groups suggests explosive potential, it is usually necessary to confirm this hazard via experimental studies.

## *Reactive Hazards*

These reactionary materials can cause damage to the human body by release of gases that will burn, explode, or produce high pressure that can inflict injury to a person nearby. In some cases, the reactionary materials may release substances that are considerably more toxic than themselves. HCS has defined three types of reactive hazards: organic peroxides, unstable (reactive) materials, and water-reactive materials.

### *Organic Peroxide*

The HCS definition for organic peroxide is "an organic compound that contains the bivalent -O-O structure and which may be considered a structural derivative of hydrogen peroxide where one or both of the hydrogen atoms has been replaced by an organic radical."

The peroxide functional group (–O-O) is relatively unstable and most organic peroxides will spontaneously decompose at a slow rate. Some organic peroxides, however, are capable of very violent reactions with detonation at environmental temperatures, causing fires and explosions. Several organic peroxides are used in the plastics industry to initiate polymerization and serve as cross-linking agents. Recognizing an organic peroxide is quite simple - the presence of the peroxide group (-O-O) in its chemical structure. However, the characterization of the severity of the hazard is

usually based upon fairly extensive laboratory testing. Examples of organic peroxides are benzoyl peroxide and allyl hydroperoxide.

### *Unstable (Reactive) Material*

The HCS definition for an unstable (reactive) material is a "chemical which in the pure state, or as produced or transported, will vigorously polymerize, decompose, condense, or will become self-reactive under conditions of shocks, pressure or temperature."

The main difference between an unstable material and an explosive is the rate of the reaction. While the rate of reaction for unstable materials is less than in the case of explosives, the unstable materials can still present a serious hazard due to the generation of high temperatures and pressures. In some cases, the reaction may be rapid enough to approach explosive potential.

Polymerization is a reaction in which small molecules (usually monomers) react with each other to form larger molecules (polymers). In the chemical process, a large amount of heat may be released. This raises the temperature of the monomer mixture that further accelerates the polymerization process until the reaction runs away or explodes.

Decomposition reactions can occur with many chemicals and mixtures. In this process, complex molecules dissociate to form simpler substances. This process may require input of heat or there may be a release of heat during the chemical reaction. The most hazardous reactions are those in which heat is released. If the reactions take place within a vessel, the high temperature may increase the vessel pressure to the point it ruptures or explodes. Examples of unstable materials are acrylonitrile and butadiene.

### *Water-Reactive Material*

The HCS definition for water-reactive material is a "chemical that reacts with water to release a gas that is either flammable or presents a health hazard."

Many chemicals fall in this category. For example, sodium and potassium, when exposed to water, will react and release hydrogen presenting an explosive hazard. Carbides (e.g., calcium carbide) can generate acetylene, a highly flammable gas, when exposed to water. In other cases, the gases released may be highly toxic as in the case of cyanide that can be released when an inorganic salt containing cyanide (e.g., potassium cyanide) comes in contact with water.

## Health Hazards

To define with precision every possible health effect that can occur in the workplace as the result of chemical exposure is an unrealistic goal. There can be a variety of toxic effects on different organs, which may depend upon dose level, frequency, duration, and route of exposure. This does not negate the need for employees to be informed of such effects and be protected from them. The HCS provides a list of the most common health hazards. However, it should be stressed that the list does not include all health hazards.

Some of the health hazard definitions provide for an extremely precise testing procedure (e.g., test species or weight range). This is because those test protocols had been codified in previous government regulations. However, other test methods have been developed and are acceptable for hazard determination. In view of this, Appendix A of the HCS indicates that if there are available scientific data that involve other animal species or test methods, they must also be evaluated to determine their applicability.

Assigning chemicals to discrete health hazard categories is not precise, and several schemes have been proposed. Separation into acute and chronic health hazards is used by the American National Standards Institute (ANSI) in its labeling standard (ANSI Z129.1). The main difference between acute and chronic is related to duration of exposure and to the rapidity of onset after exposure.

In some exposure situations, the effects may occur rapidly after a single or short-term exposure (acute effects); in other cases, the damage may accumulate after multiple exposures or over a long exposure period, or arise long after earlier exposures (chronic effects). Examples of chronic effects are cancer and cirrhosis of the liver. A chemical may have the ability to cause both acute and chronic effects. For example, ethyl alcohol can cause death when consumed in large amounts at one time, birth defects when consumed for only a few days by a pregnant woman, and cirrhosis of the liver if consumed for several years. OSHA has listed a number of health hazards, some general or systemic (whole-body) effects, and others that are specific to certain organs (target organs).

Following is a brief description of the HCS identified health hazards. In many cases, the determination is based on data obtained from standard experiments with laboratory animals. Reliable human data is prefered to animal data. However, in many cases, reliable human data are not available, and animal data must be used. The search strategy previously discussed should attempt to obtain

human data, animal data, and cell and tissue studies, as well as data on the mechanisms by which a chemical causes toxicity.

## *Systemic Effects*

### *Carcinogen*

Under the HCS, “a chemical is considered to be a carcinogen if:

(a) It has been evaluated by the International Agency for Research on Cancer (IARC), and found to be a carcinogen or potential carcinogen; or

(b) It is listed as a carcinogen or potential carcinogen in the Annual Report on Carcinogens published by the National Toxicology Program (NTP) (latest edition); or,

(c) It is regulated by OSHA as a carcinogen.”

OSHA has accepted the prior hazard determination of these expert organizations that have reviewed the human and animal research studies and have concluded that the chemicals listed represent human cancer risks.

**Probable human carcinogens have been listed by OSHA, NTP, and IARC.**

As might be expected, there is considerable overlap in these lists as more than one of the scientific organizations may have come to the same conclusion regarding cancer potential. Some examples of workplace carcinogens are asbestos, benzene, lead chromate, beryllium and vinyl chloride.

The simple definition of a carcinogen is "a substance that has the potential to cause cancer." The terminology used to describe cancer may be confusing. Cancer is a type of tumor. A tumor (also known as a neoplasm) is simply an uncontrolled growth of cells. Tumors may be benign or malignant. Benign tumors grow only at the site of origin, and do not invade adjacent tissues or go to distant sites in the body (known as "metastasis"). Except for those that develop deep in vital organs (such as the brain), benign tumors can be successfully treated (usually by surgical removal) and the potential for causing death is low. Malignant tumors are cancers and can grow outside their original site in an organ, invade surrounding tissue, or metastasize to distant organs where they can

start new growths of the cancerous tissue. Malignant tumors (cancer) are difficult to treat and frequently cause death of the patient.

Cancers vary greatly in type and behavior in the body. Some cancers grow slowly and rarely metastasize. Others are highly invasive and metastasize rapidly. Cancers are usually named for the specific cell type or organ of origination. For example, squamous cell carcinoma of the lung is a cancer that arose from a squamous cell in the lung. A hepatocellular carcinoma is a cancer arising from a liver cell (hepatocyte). Sometimes the name given to a cancer also reflects its nature. For example, chronic lymphocytic leukemia is a cancer involving lymphocytes (a type of blood cell) which the leukemia is chronic or long-lasting in nature. OSHA, NTP, and IARC report the specific types of cancer caused by chemicals that they list.

***How do IARC, NTP, and OSHA classify a substance as a "carcinogen"?***

The operational criteria for labeling or designating a substance as a "carcinogen", as used by the IARC, NTP, and OSHA, relate strictly to the substance's potential for causing cancer in humans. The finding that a substance produced cancer in an experimental animal study does not necessarily result in IARC, NTP, or OSHA designating the substance as a "human carcinogen." These organizations use a "weight of evidence" analysis which includes review of data from animal studies, human epidemiological evidence, and data from cell and tissue studies.

In some cases the collective evidence is substantial and the substance is designated as a "known human carcinogen." In other cases the evidence for human carcinogenicity is not as strong and the substance warrants designation only as a "potential" or "possible" human carcinogen. In the HCS definition of "carcinogen", the terms "carcinogen" and "potential carcinogen" are used. "Carcinogen" in HCS terms relates to the IARC category "Group I - The Agent is Carcinogenic to Humans, and the NTP category for "Substances …Known to be Carcinogenic."

"Potential carcinogens" in HCS terms relates to the IARC category "Group 2A - The Agent is Probably Carcinogenic to Humans", and to the NTP category for "Substances …Which May Reasonably be Anticipated to be Carcinogens."

IARC has a third classification of concern to OSHA. This is Group 2B - "The Agent is Possibly Carcinogenic to Humans." This classification does not rise to the level of concern for Group 2A and therefore those substances are not designated as OSHA carcinogens and the labels for those substances do not require

labeling as a carcinogen. However, the fact that IARC has placed a substance into Category 2B should be included on material safety data sheets.

Reports in the periodic literature (e.g., journals) or laboratory reports (e.g., NTP bioassay reports) may indicate positive results from cancer studies of chemicals not listed by OSHA, NTP, or IARC as carcinogens. Some literature reports lack information on experimental design, age of individual animals when tumors were found, purity of chemical tested, etc., making scientific analysis difficult and uncertain. For this reason, a "weight of evidence" approach is used to evaluate the strength of evidence pertaining to human carcinogenicity. The recommended approach is not to discard such information but to collect and make it a part of the information profile for the substance. The results of such studies should be listed on the MSDS. However, the positive results are not sufficient to designate the substance as a carcinogen (and to label it as such). The carcinogen designation is reserved for those substances that have been so designated by IARC, NTP, or OSHA.

### *Toxic Agents*

The HCS classifies chemical agents as toxic or highly toxic based on the number of deaths that occur following brief (acute) exposure of rodents. The difference in the two categories is strictly the dose at which the toxicity (death) occurs. Exposure is by the three major workplace exposure routes, mouth (oral), skin (dermal), or breathing (inhalation). The analysis is based on the $LD_{50}$ (median lethal dose by oral or dermal exposure) and $LC_{50}$ (median lethal inhalation concentration for a one-hour exposure. The $LD_{50}$ and $LC_{50}$ represent the dose or concentration, respectively, at which 50% of the test animals (and supposedly humans) will be expected to die.

Under the HCS, a highly toxic chemical is "a chemical falling within any of the following categories:

(a) A chemical that has a median lethal dose ($LD_{50}$) of 50 milligrams or less per kilogram of body weight [units listed as mg/kg] when administered orally to albino rats weighing between 200 and 300 grams each.

(b) A chemical with a median lethal dose ($LD_{50}$) of 200 milligrams or less per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each.

(c) A chemical that has a median lethal concentration ($LC_{50}$) in air of 200 parts per million (units listed as ppm) by volume or less of gas or vapor, or 2

milligrams per liter [units listed as mg/l] or less of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each."

Under the HCS, a toxic chemical is "a chemical falling within any of the following categories:

(a) A chemical that has a median lethal dose ($LD_{50}$) of more than 50 milligrams per kilogram but not more than 500 milligrams per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.

(b) A chemical that has a median lethal dose ($LD_{50}$) of more than 200 milligrams per kilogram but not more than 1,000 milligrams per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each.

(c) A chemical that has a median lethal concentration ($LC_{50}$) in air of more than 200 parts per million but not more than 2,000 parts per million by volume of gas or vapor, or more than two milligrams per liter but not more than 20 milligrams per liter of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within 1 hour) to albino rats weighing between 200 and 300 grams each."

The following table illustrates how a chemical can be classified as a **highly toxic** or **toxic** depending on the results of the appropriate animal tests.

| Animal Test | Highly Toxic | Toxic |
|---|---|---|
| Oral $LD_{50}$ | $\leq$ 50 mg/kg | 50-500 mg/kg |
| Dermal $LD_{50}$ | $\leq$ 200 mg/kg | 200-1000 mg/kg |
| Inhalation $LC_{50}$ - gases, vapors | $\leq$ 200 ppm | 200-2000 ppm |
| Inhalation $LC_{50}$ - mists, fumes or dust | 2 mg/L | 2-20 mg/L |

Remember the HCS instructions pertaining to whether a study is scientifically acceptable for hazard determination. While only one positive study is required, it must be:

- conducted in accordance with established scientific principles; and
- the results must be statistically significant.

As can be seen, the acute toxicity for a *toxic* agent is considerably less than with the *highly toxic* agents. For example, the break point

for oral exposures is 50 mg/kg. Below 50 mg/kg, the chemical is *highly toxic* whereas if the $LD_{50}$ is above 50 mg/kg, it is only *toxic*. Examples of *highly toxic* chemicals are parathion (with an oral rat $LD_{50}$ of 2 mg/kg and a dermal $LD_{50}$ of 22 mg/kg) and methyl isocyanate (with an inhalation one-hour $LC_{50}$ in rats of 45 ppm). Examples of *toxic* chemicals are chloroform (with an $LD_{50}$ of 140 mg/kg), acrylonitrile (with an 24-hour dermal $LD_{50}$ between 200 and 2000 mg/kg), and ammonia (with an inhalation one-hour $LC_{50}$ in rats between 200 ppm and 2000 ppm). Agents having an oral $LD_{50}$ greater than 500 mg/kg are not classified as *toxic*. This does not mean that they do not represent a health hazard (e.g., the chemical could present a chronic hazard, such as cancer or hepatotoxicity), but only that they are not classified as *toxic* under the HCS.

While these criteria are based on laboratory animals that are quite different than humans, the relative response between animals and humans is generally comparable on a per body weight basis. Thus, expressing the effect in terms of kilogram of body weight provides a satisfactory basis for determining potential human effects based on animal research results. Translating a 50 mg/kg $LD_{50}$ to an understandable situation in humans, if a group of 150-pound humans ingested about one-half teaspoon of such a chemical, approximately 50% would be expected to die.

The HCS provides criteria for classifying chemicals as *highly toxic* and *toxic* based on experiments that used 200-300 gram albino rats or 2-3 kilogram albino rabbits. However, current testing procedures accept other species and do not prescribe exact weights. Although specific criteria are provided, the HCS also indicates that information pertaining to other species and test methods is also relevant. In determining hazards, you need to search for and analyze all data pertaining to toxicity and make judgments as to whether the tests were conducted using appropriate and accepted methodology. If the studies are acceptable, the data should be used as appropriate to determine whether the chemical is *highly toxic*, *toxic*, or belongs to another health hazard category (e.g., hepatotoxicity or irritant).

### *Irritant*

Under the HCS, an **irritant** is "A chemical, which is not corrosive, but which causes a reversible inflammatory effect on living tissue by chemical action at the site of contact. A chemical is a skin irritant if, when tested on the intact skin of albino rabbits by the methods of 16 CFR 1500.41 for four hours exposure or by other appropriate techniques, it results in an empirical score of five or more. A chemical is an eye irritant if so determined under the

**Irritant - reversible inflammatory reaction**

procedure listed in 16 CFR 1500.42 or other appropriate techniques."

The difference between an *irritant* and a *corrosive* is the ability of the body to repair the tissue reaction. With irritants the inflammatory reaction can be reversed whereas with corrosive damage it is permanent or irreparable. The site of irritation is often the skin or eye but can also be any mucous membrane or other tissue that the chemical comes in contact with. This could include the mouth or throat if the irritant is swallowed, and the nose or lungs if the irritant is inhaled. If an immunologic mechanism (allergy) is responsible for the tissue reaction, the material will be classified as a sensitizer rather than an irritant. Examples of irritants are acetic acid, ammonia, and isopropyl alcohol. The standard toxicology test for inflammation consists of the application of a substance to the shaved skin of white rabbits. White rabbits have been widely used as the irritation is easy to detect and the results have been shown to be highly predictive of potential skin effects in humans. Data obtained with other strains or species can also be used in the determination of irritation potential.

### *Corrosive*

The HCS definition for **corrosive** is "A chemical that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact. For example, a chemical is considered to be corrosive if, when tested on the intact skin of albino rabbits by the method described by the U.S. Department of Transportation in appendix A to 49 CFR part 173, it destroys or changes irreversibly the structure of the tissue at the site of contact following an exposure period of four hours. This term shall not refer to action on inanimate surfaces."

**Corrosion - irreversible tissue injury**

Corrosion is manifested by ulcers, cell death, and scar formation. The site of a corrosive effect can be any place on the body that the chemical contacts. This is often the skin or eye but can also be any mucous membrane (such as the mouth or esophagus if swallowed and the nose and trachea if inhaled).

Generally speaking, corrosive materials have a very low pH (acids) or a very high pH (bases). Strong bases are usually more corrosive than acids. Examples of corrosive materials are sodium hydroxide (lye) and sulfuric acid.

The standard toxicology test for corrosivity uses white rabbits with the material applied to the shaved (but not damaged) skin. Experience has shown that results obtained with white rabbits are highly predictive of potential skin effects in humans. Corrosion

determined using other species and procedures must also be considered in the decision as to classification as a corrosive.

### *Sensitizer*

**Sensitizer - produces hyperallergic condition**

The HCS definition for **sensitizer** is "A chemical that causes a substantial proportion of exposed people or animals to develop an allergic reaction in normal tissue after repeated exposure to the chemical."

A sensitizer (allergen) causes little or no reaction in man or test animals on first exposure. The problem arises on subsequent exposures when a marked immunological response occurs. The response is not necessarily limited to the contact site as it may be a generalized body condition. Skin sensitization is common in industry. Respiratory sensitization and generalized hyperallergy to a few chemicals has also been known to occur. Well-known examples of sensitizers are toluene diisocyanate, nickel compounds, and poison ivy.

## *Target Organ Effects*

### *Hepatotoxin*

**Hepatotoxin - liver toxin**

The HCS definition for **hepatotoxins** is “chemicals which produce liver damage”. Signs of hepatotoxicity may include jaundice and liver enlargement. Hepatotoxicity includes not only the liver but also the gall bladder and bile duct. The liver is particularly susceptible to foreign chemicals because of its large blood supply and the major role it plays in metabolism. These factors can result in exposure to high doses of a toxicant and the production and immediate exposure to potentially toxic metabolites.

The primary forms of hepatotoxicity are: chemical hepatitis (inflammation of the liver), fatty liver or steatosis (lipid accumulation in hepatocytes), hepatic necrosis (death of the hepatocytes), cholestasis (stoppage of bile flow and backup of bile salts in the liver), cirrhosis (chronic fibrosis, often due to alcohol), hypersensitivity (immune reaction resulting in hepatic necrosis) and hepatic cancer (cancer of the liver). Examples of hepatotoxins are arsenic, carbon tetrachloride, ethyl alcohol, halothane, and vinyl chloride.

### *Nephrotoxin*

The HCS definition for **nephrotoxins** is “chemicals which produce kidney damage”. Signs often include edema and proteinuria. The kidney is highly susceptible to toxicants for two reasons. There is a very high volume of blood flow through the kidney, and the kidney can filter large amounts of toxins that can concentrate in the kidney tubules. The kidney eliminates body wastes, maintains body levels of electrolytes and fluids, and produces special enzymes and hormones that regulate blood pressure, pH, calcium, and the production of red blood cells. Thus, the effects of nephrotoxicity are systemic in nature, such as hypertension, body fluid and electrolyte imbalance, and anemia. The primary forms of nephrotoxicity are nephritis (inflammation of the kidneys), glomerulonephritis (damage to the glomerulus portion of the nephron), and acute or chronic renal failure.

**Nephrotoxin - kidney toxin**

Examples of nephrotoxins are heavy metals (e.g., chromium, lead, mercury, and uranium) and halogenated hydrocarbons (e.g., carbon tetrachloride and chloroform). While some toxins cause acute effects, many exert their toxicity by long-term exposure at lower levels.

***Neurotoxins***

The HCS definition for **neurotoxins** is "chemicals which produce their primary toxic effects on the nervous system." The nervous system directs many of the body's activities so that changes in the nervous system may be apparent throughout the body. Electrical impulses move through the body via neurons (nerve fibers). Toxins can damage cells of the central nervous system (brain and spinal cord) or the peripheral nervous system (nerves outside the central nervous system).

**Neurotoxin - nervous system toxin**

The primary types of neurotoxicity are: neuronopathies (neuron injury), axonopathies (axon injury), demyelination (loss of axon insulation), and interference with neurotransmission. Signs and symptoms of neurotoxicity include narcoses, behavioral changes, and decreases in motor function. Examples of neurotoxins are carbon disulfide, ethylene oxide, hexane, lead, and mercury.

***Blood/Hematopoietic Toxin***

Blood/hematopoietic toxins are also referred to as hemotoxins or hematotoxins. The HCS defines these chemicals as "Agents which act on the blood or hemato-poietic system: Decrease hemoglobin function; deprive the body tissues of oxygen."

**Hemotoxin - toxicity to bone marrow or circulating blood cells**

While one might consider the blood and hematopoietic system as independent tissues, they are intimately related. The hematopoietic system gives rise to the blood elements (cells and platelets). Toxins can act at various points in the hematopoietic/blood system. Some affect the circulating blood elements interfering with their function. Others damage the hematopoietic system and may prevent it from producing the blood elements.

The formed elements (cells and platelets) in the circulating blood are usually not directly affected by toxins. An exception are the red blood cells (erythrocytes). Several toxic agents can bind with the hemoglobin of the red blood cells and interfere with transport of oxygen to body tissues (hypoxia). Examples of chemicals that bind with hemoglobin and cause hypoxia, by interfering with oxygen transporting capability of the blood, are carbon monoxide, sodium nitrite, and hydrogen sulfide. Cyanides also cause hypoxia by interfering with the tissue cell's ability to utilize oxygen.

The more common form of hemotoxicity results from chemicals acting directly on the hematopoietic tissues (blood-forming tissue). The primary effect is a decrease in formation of specific blood cells so that the number in the circulating blood is reduced, impairing their ability to function normally. For example, phenothiazine and anticonvulsant drugs can damage the bone marrow cells that give rise to the granuloctyes and decreased ability to fight infections. Aspirin and nitroglycerin can be toxic to megakaryocytes that produce blood platelets. The decrease in platelets impairs blood-clotting capability. Other toxins, e.g., arsenic, benzene, and chlordane can cause a decrease in the formation of all blood elements, a condition known as aplastic anemia. Cancer of the hematopoietic tissues (primarily acute myelogenous leukemia) also occurs due to exposure to some industrial chemicals and drugs, for example, benzene, chloramphenicol, and phenylbutazone.

### *Respiratory Toxin*

**Respiratory toxin - affects lung and other areas of respiratory system**

The HCS definition for **agents which damage the lung** is "chemicals which irritate or damage pulmonary tissue." These are commonly known as **respiratory toxins.**

The primary function of the respiratory system is to deliver oxygen to the bloodstream and remove carbon dioxide from the blood. Thus, damage to the respiratory tissues interferes with blood/gas exchange that may cause serious malfunction of all tissues of the body, especially the brain and heart. Respiratory toxicity can occur in the upper respiratory system (nose, pharynx, larynx, and trachea) or in the lower respiratory system (bronchi, bronchioles, and lung alveoli). The primary types of respiratory toxicity are pulmonary irritation, asthma/bronchitis, reactive airway disease,

emphysema, allergic alveolitis, fibrotic lung disease, pneumoconiosis, and lung cancer. Some exert their toxicity quickly (acute effects, such as pulmonary irritation) while others act over a long period to time (chronic effects, such as pulmonary fibrosis). Examples of respiratory toxins are asbestos, formaldehyde, ozone, nitrogen dioxide, and silica.

### *Reproductive Toxin*

The HCS definition for **reproductive toxins** is "chemicals which affect the reproductive capabilities including chromosomal damage (mutations) and effects on fetuses (teratogenesis)." This definition is comprehensive and incorporates toxic effects on all elements of the process of reproduction, including damage to the germ cells (sperm and ova).

**Reproductive toxicity - includes sterility, abortion, birth defects, child mortality and childhood cancer**

Thus, a wide variety of effects can occur, including sterility, decreased libido, impotence, interrupted pregnancy (abortion, fetal death, or premature delivery), birth defects in the offspring, altered sex ratio and multiple births, chromosome abnormalities, childhood morbidity, and childhood cancer. Examples of reproductive toxins are lead and 1,2-Dibromo-3-chloropropane (DBCP). Reproductive toxicity can involve toxicant damage to either the male or female reproductive system. Those substances that can cause birth defects are referred to as teratogens.

The term developmental toxicity refers to adverse effects observed in the embryo, fetus or newborn. In testing, these reproductive effects are usually considered separately from those effects on an adult animal's capacity to successfully mate (fertility) and deliver and nurture offspring (perinatal and postnatal development and maternal function). Developmental toxicity can result from toxicant exposure to either parent before conception or to the mother and her developing embryo-fetus. The three basic types of developmental toxicity are: *Embryolethality* which is the failure to conceive, spontaneous abortion or stillbirth; *embryotoxicity* which is the growth retardation or delayed growth of specific organ systems, and *teratogenicity* which pertains to irreversible conditions that leave permanent birth defects in live offspring (e.g. cleft palate, missing limbs).

Chemicals can cause developmental toxicity by two mechanisms. They can act directly on cells of the embryo causing cell death or cell damage that leads to abnormal organ development. A chemical might also induce a mutation in a parent’s germ cell that is transmitted to the fertilized ovum. Some mutated fertilized ova develop into abnormal embryos.

*Genetic toxicity* has also been included in the HCS definition of reproductive toxins. Genetic effects result from damage to DNA and altered genetic expression. This process is known as *mutagenesis*. The genetic change is referred to as a mutation and the agent causing the change as a *mutagen*. There are three types of genetic change: *Gene mutation* is a change in DNA sequence within a gene. C*hromosome aberrations* are changes in the chromosome structure. *Aneuploidy/polyploidy* is an increase or decrease in number of chromosomes

If the mutation occurs in a germ cell (sperm and ova) the effect can be heritable. There is no effect on the exposed person, rather the effect is passed on to future generations. If the mutation occurs in a somatic cell (all body cells except sperm and ova), it can cause altered cell growth (e.g. cancer) or cell death (e.g. teratogenesis) in the exposed person.

### *Cutaneous Hazard*

The HCS definition for **cutaneous hazards** is "chemicals which affect the dermal layer of the body." This overlaps to a certain extent with the previously described hazards, irritant and corrosive. However, here we are concerned only with effects of toxins on the skin. A variety of skin conditions can arise from exposure to toxic substances. Contact dermatitis or inflammation of the skin can be of two types, irritant dermatitis and allergic contact dermatitis. The basic inflammatory reaction is the same but the cause and progress of the dermatitis differs. With irritant dermatitis the effect is immediate without prior exposure, whereas the allergic dermatitis requires previous exposure with the development of allergy or sensitization. Contact dermatitis is common in industry and usually consists of redness (erythema), thickening and firmness of skin (induration), flaking (scaling), and blisters (vesiculation). Normally, the contact dermatitis is reversible if the irritant or allergen is removed.

**Cutaneous hazard - irritation, corrosion, allergy, pigment changes, cancer**

In contrast, chemical burns can sometimes occur in which immediate necrosis, ulceration, and sloughing of the skin occurs. This injury may be permanent and can leave deep wounds that scar or require transplanted skin to repair the damaged area. Some chemicals can cause irritation by defatting of the skin; for example, commonly used ketones or chlorinated compounds, such as the solvents trichloroethylene, methylene chloride, and gasoline.

Cutaneous hazards may cause skin reactions that are neither irritation or allergic reactions. Oils and halogenated aromatic hydrocarbons can cause acne, mercury and lead can cause increased pigmentation of the skin, hydroquinone can cause decreased pigmentation, and beryllium and chromium can stimulate

a granulomatous reaction (having the appearance of small, benign tumors). Skin cancer can be induced by workplace exposure to UV light and arsenic.

### *Eye Hazard*

The HCS definition for **eye hazards is** "chemicals which affect the eye or visual capacity." The primary toxic effects from direct exposure of chemicals to the eye are conjunctivitis or corneal damage. Conjunctivitis is inflammation of the conjunctiva, the delicate membrane that lines the eyelids and covers the eyeballs. The cornea is the transparent front surface of the eyeball.

**Eye hazard – from direct chemical contact with conjunctiva or cornea, or from agent that travels through the bloodstream to the optic nerve and retina.**

Chemicals that accidentally splash onto the face can directly contact either of these eye structures. Acids and strong alkalis (such as lye) may cause severe corneal corrosion and may result in permanent blindness. Organic solvents (such as acetone) and detergents can cause temporary clouding of vision, primarily due to dissolving of fats from the cornea.

Some chemicals can cause toxic effects to the eye even if they do not directly contact the eye. Chemicals that are inhaled or ingested may move to the eye through the blood circulation and produce eye damage. 2-4-Dintrophenol (wood preservative) can cause cataracts after ingestion. The ingestion of thallium salts (in pesticides) and methanol (wood alcohol) has been associated with blindness due to damage to the optic nerve. Retina damage has been associated with exposures to arsenicals and carbon disulfide.

While animal ocular tests are routinely conducted during the safety testing of new chemicals, detection of damage to the optic nerve and retina are difficult to detect. Unfortunately, this information results from case reports of humans exposed to toxic substances. Irritation and corrosion may be predicted on the basis of the pH of the chemical substance. However, pH has little value in predicting other types of ocular toxicity.

### *Other Types of Target Organ Hazards*

As previously indicated, the HCS does not identify all possible target organ effects due to exposure to toxic agents. Certain chemicals may target one or more specific organs not listed in the HCS. Based on the chemistry of the toxin and how it is metabolized and distributed in the body, virtually any organ or organ system may be at potential risk. Therefore data found in the

**Industrial chemicals can cause toxicity of the cardiovascular system and immune system.**

literature search pertaining to other organs must also be evaluated and documented. Of the other important health hazards listed in Table 2, effects on the cardiovascular system and immune system are most likely to be reported for industrial chemicals.

**Cardiovascular toxicity** has been reported for several industrial chemicals. The effects on the heart are primarily interference with cardiac nerve transmissions or damage to the heart musculature (cardiomyopathy). Either type of effect can prevent the heart from contracting (beating) normally so that the blood is not adequately circulated through the body, resulting in multiple organ damage and dysfunction. Some chemicals can also affect the circulatory vessels (veins, arteries and capillaries). Examples of cardiovascular toxins are ethanol and cobalt (cardiomyopathy); arsenic (arteriosclerosis and vascular lesions); toluene and halogenated alkanes (arrhythmias); and mercury (aortic lesions).

**Toxicity to the Immune System** can lead to several different effects, depending on which cells are damaged, and whether the toxic effects are due to impairment of the immune system (immunosuppression) or the effects are caused by an altered or enhanced immune system (e.g., allergy/hypersensitivity and autoimmunity). A wide variety of industrial chemicals are known to be immunotoxins, including toluene diisocyanate, formaldehyde, silicone, benzene, heavy metals, halogenated aromatic hydrocarbons, and insecticides.

## DATA DOCUMENTATION

The fourth and final step in the hazard determination process is very important. All the other steps will be wasted if you do not document your findings carefully. If a chemical is found to be hazardous, the findings should be documented in order to assist in preparing labels and MSDSs, and to maintain a record for future reference and updating. In addition, the HCS requires data documentation of the hazard determination as follows:

> Chemical manufacturers, importers, or employers evaluating chemicals shall describe in writing the procedures they use to determine the hazards of the chemical they evaluate. The written procedures are to be made available, upon request, to employees, their designated representatives, the Assistant Secretary and the Director [OSHA and NIOSH officials]. The written description may be incorporated into the written hazard communication program required under paragraph (e) of this section [the HCS].

**Document the following:**

- **Chemical inventory**
- **Procedures used in hazard determination**
- **Hazardous chemicals list.**

To meet the HCS requirements, it is recommended that a structured approach to data retrieval and compilation be adopted. This structured approach applies to preparation of MSDSs and labels. Compilations of four types of data are considered essential:

- Initial chemical inventory;
- Description of procedures used for hazard determination;
- Specific data retrieved for each chemical; and
- Hazardous chemicals list

### *Chemical Inventory*

The **chemical inventory** should consist of all chemicals that are produced, imported, or used by the company. The chemical inventory should be complete and contain, as a minimum, the following:

- chemical name;
- CAS Number;
- common name;
- synonyms;
- product/mixture name (if applicable); and
- percentage in product/mixture (if applicable).

It is recommended that this chemical inventory be computerized for future sorting, additions, deletions, and status reports.

### *Description of Procedures Used for Hazard Determination*

As indicated previously, the procedures used to determine hazards of chemicals are to be written down and made available upon request to employees as well as OSHA and NIOSH officials. This written description of procedures should be incorporated into the company's written hazard communication program.

The procedures used for the following hazard determination steps should be described in detail:

- Development of chemical inventory;
- Search strategy and sources used to obtain data on chemicals for which hazard determinations are conducted;
- References retrieved and used to identify each specific physical or health hazard;
- Summary for each retrieved reference that contained relevant data (retrieved computer abstracts can be used);
- Summary of important data that was used for hazard determination; and
- Identification of hazards.

### *Specific Data Retrieved for Each Chemical*

It is recommended that data be organized so as to facilitate the preparation of MSDSs and labels. Listing all the hazard categories and the relevant data obtained for each hazard will also facilitate the gathering of data and document the effectiveness and completeness of the hazard determination process. When data are not located for a specific type of hazard or when a specific hazard would not occur due to the chemical or physical form of the chemical, this should be indicated.

The retrieved data should be listed in the basic format of the MSDS in order to facilitate preparation of MSDSs and labels, as well as allow for future updating as the need arises. It is highly recommended that the data be computerized and archived in a secure location for future use. A commonly used title for hazard data compilations for specific chemicals is **hazards profile.**

**LIST OF DATA TO INCLUDE IN THE HAZARDS PROFILE FOR A CHEMICAL**

**COMPANY INFORMATION**

- Company Name
- Name of Responsible Company Official
- Date Prepared

**HAZARDOUS INGREDIENTS/IDENTITY INFORMATION**

- Chemical Name
- CAS Number
- Common Name
- Synonyms
- Product/Mixture Name (If Applicable)
- Percentage In Product/Mixture (If Applicable)

**PHYSICAL/CHEMICAL CHARACTERISTICS**

- Boiling Point
- Freezing Point
- Vapor Pressure (mm Hg.)
- Vapor Density (air = 1)
- Specific Gravity ($H_2O$ = 1)
- Melting Point
- Evaporation Rate (Butyl Acetate = 1)
- Solubility in Water
- Appearance and Odor

**FLAMMABILITY/EXPLOSIVITY DATA**

- Autoignition Temperature
- Flammable Range
- Flash Point (indicate method used)
- Lowest Explosive Limit (LEV)
- Upper Explosive Limit (UEL)
- Extinguishing Media
- Special Fire Fighting Procedures
- Unusual Fire and Explosion Hazards
- Extinguishant

**REACTIVITY DATA**

- Stability - conditions to avoid
- Incompatibilities - materials to avoid
- Hazardous Decomposition or Byproducts
- Hazardous Polymerization – conditions to avoid

| **SUMMARY - Fire and Explosion Hazard** | **HAZARD Yes/No** | **Reference** |
|---|---|---|
| Combustible liquid | | |
| Flammable aerosol | | |
| Flammable gas | | |
| Flammable liquid | | |
| Flammable solid | | |
| Oxidizer | | |

| | | |
|---|---|---|
| Pyrophoric material | | |
| Compressed gas | | |
| Explosive | | |
| Organic peroxides | | |
| Unstable material | | |
| Water-reactive material | | |

**HEALTH HAZARD DATA**

- Routes of Entry
- Odor Threshold
- OSHA PEL
- ACGIH TLV
- NIOSH IDLH
- NIOSH REL
- Cancer Classifications:
  - OSHA
  - NTP
  - IARC

| **SUMMARY - Health Hazards** | **HAZARD Yes/No** | **Reference** |
|---|---|---|
| **Systemic Effects** | | |
| Carcinogen | | |
| Highly toxic | | |
| Toxic | | |
| Irritant | | |
| Corrosive | | |
| Sensitizer | | |
| **Target Organ Effects** | | |
| Hepatotoxin | | |
| Nephrotoxin | | |
| Neurotoxin | | |
| Blood/hematopoietic toxin | | |
| Respiratory toxin | | |
| Reproductive toxin | | |
| Cutaneous hazard | | |

| | | |
|---|---|---|
| Eye hazard | | |
| Cardiovascular toxin | | |
| Immune toxin | | |
| Other type of toxicity | | |

## APPENDICES

A. Glossary of Terms and Definitions
B. Recommended Literature Sources
C. OSHA Toxic and Hazardous Substances
D. OSHA Carcinogens
E. NTP Carcinogens
F. IARC Carcinogens

# APPENDIX A
# GLOSSARY OF TERMS AND DEFINITIONS

The following glossary presents brief explanations of acronyms and common terms used in this document.

**Absorbed Dose.** The amount of a substance that actually enters into the body, usually expressed as milligrams of substance per kilogram of body weight (mg/kg).

**ACGIH.** The American Conference of Governmental Industrial Hygienists is an organization of government and academic professionals engaged in occupational safety and health programs. ACGIH establishes recommended occupational exposure limits for chemical substances and physical agents known as Threshold Limit Values; see TLV.

**Acid.** Any chemical that undergoes dissociation in water with the formation of hydrogen ions. Acids have a sour taste and may cause severe skin burns. Acids have pH values below 7.

**Acute Dose.** The amount of a substance administered or received over a very short period of time (minutes or hours), usually within 24 hours.

**Acute Toxicity.** The toxic effects resulting from a single dose or short exposure to a substance.

**Alkali.** Also referred to as bases, alkalis have pH values above 7. They may be irritating or corrosive (caustic) to the skin, eyes and mucous membranes, especially at very high pH levels.

**Allergic Reaction**. An abnormal immunologic response in a person who has become hypersensitive to a specific substance. Some forms of dermatitis and asthma may be caused by allergic reactions to chemicals.

**ANSI.** The American National Standards Institute is a privately funded, voluntary membership organization that identifies industrial and public needs for national consensus standards and coordinates development of such standards.

**ASTM.** The American Society for Testing and Materials develops voluntary consensus standards for materials, products, systems, and services. ASTM is a resource for sampling and testing methods, information on health and safety aspects of materials, safe performance guidelines, and effects of physical agents, biological agents, and chemicals.

**Auto-ignition Temperature.** The approximate lowest temperature at which a flammable gas or vapor-air mixture will spontaneously ignite without spark or flame. It is also the temperature to which a closed, or nearly closed container must be heated in order that the flammable liquid, when introduced into the container, will ignite spontaneously or burn.

**Benign.** Not recurrent or not tending to progress; not cancerous.

**Boiling Point-BP.** The temperature at which a liquid changes to a vapor state at a given pressure. The boiling point is usually expressed in degrees Fahrenheit at sea

level pressure (760 mmHg, or one atmosphere). For mixtures, the **initial** boiling point or the **boiling range** may be given. Flammable materials with low boiling points generally present special fire hazards.

**CAS Number.** A number assigned to a specific chemical by the Chemical Abstracts Service, an organization operated by the American Chemical Society. CAS Numbers are used internationally to identify specific chemicals or mixtures.

**Carcinogenicity.** The complex process whereby normal body cells are transformed to cancer cells.

**cc.** Cubic centimeter is a volume measurement in the metric system that is equal in capacity to one milliliter (ml). One quart is approximately 946 cubic centimeters.

**CFR.** Code of Federal Regulations. A collection of the regulations that have been promulgated under United States Law.

**Chemical Name.** The name given to a chemical in the nomenclature system developed by the International Union of Pure and Applied Chemistry (IUPAC) or the Chemical Abstracts Service (CAS). The scientific designation of a chemical or a name that will clearly identify the chemical for hazard evaluation purposes.

**Chronic Toxicity.** Adverse effects resulting from repeated doses or exposures to a substance over a relatively prolonged period of time.

**Decomposition.** Breakdown of a material or substance (by heat, chemical reaction, electrolysis, decay, or other processes) into parts or elements or simpler compounds.

**Dermal.** Relating to the skin.

**DNA.** Deoxyribonucleic acid; the molecules in the nucleus of the cell that contain genetic information.

**Dose.** The amount of a substance received at one time. Dose is usually expressed as administered or absorbed dose (e.g., milligrams material/kilogram of body weight).

**DOT.** U.S. Department of Transportation; the Federal agency that regulates transportation of chemicals and other hazardous and non-hazardous substances.

**Epidemiology.** The branch of science concerned with the study of human disease in specific populations, in order to develop information about the causes of disease and identify preventive measures.

**Evaporation Rate.** The rate at which a material will vaporize (evaporate) when compared to the known rate of vaporization of a standard material The evaporation rate can be useful in evaluating the health and fire hazards of a material. The designated standard material is usually normal butyl acetate (NBUAC or nBuAc), with a vaporization rate designated as 1.0. Vaporization rates of other solvents or materials are compared to the vaporization rate of the standard material and then classified as:

FAST - if greater than 3.0. Examples: Methyl Ethyl Ketone = 3.8, Acetone = 5.6, Hexane = 8.3.

MEDIUM - if 0.8 to 3.0. Examples: 190 proof (95%) Ethyl Alcohol = 1.4, VM&P Naphtha = 1.4, MIBK = 1.6.

SLOW - if less than 0.8. Examples: Xylene = 0.6, Isobutyl Alcohol = 0.6, Normal Butyl Alcohol = 0.4, Water = 0.3, Mineral Spirits = 0.1.

**Explosive Limits.** The range of concentration of a flammable gas or vapor (percent by volume in air) in which explosion can occur if an ignition source is present.

**Flammable.** A material which is easily ignited and burns.

**Flammable Aerosol.** An aerosol that, when tested by the method described in 16 CFR 1500.45 yields a flame projection exceeding 18 inches at full valve opening, or a flashback (a flame extending back to the valve) at any degree of valve opening.

**Flashback.** Occurs when flame from a torch burns back into the tip, the torch, or the hose. It is often accompanied by a hissing or squealing sound with a smoky or sharp-pointed flame.

**Flashpoint.** The minimum temperature at which a liquid gives off a vapor in sufficient concentration to form an ignitable mixture in air or oxygen. The HCS specifies that the testing should be conducted by one of the following methods:

(a) Tagliabue Closed Tester (see American National Standard Method of Test for Flash Point by Tag Closed Tester, Z11.24 1979 [ASTM D 56-79]).

(b) Pensky-Martens Closed Tester (see American National Standard Method of Test for Flash Point by Pensky-Martens Closed Tester, Z11.7-1979 ASTM D93-79]).

(c) Setaflash Closed Tester (see American National Standard Method of Test for Flash Point by Setaflash Closed Tester [ASTM D 3278-78]).

**Genetic.** Pertaining to or carried by genes; hereditary.

**Hazard.** The inherent capacity of a substance to cause an adverse effect.

**IARC.** International Agency for Research on Cancer, a component of the World Health Organization, located in Lyon, France.

**Ignitable.** A solid, liquid or compressed gas which is capable of being set afire.

**In Vitro.** Outside a living organism (e.g., in a test tube).

**Inhalation.** Breathing in of a substance in the form of a gas, vapor, fume, mist, or dust.

**Latency Period.** The period of time between an exposure and onset of toxicity.

**$LC_{50}$.** Lethal Concentration 50%. The calculated concentration at which 50% of the population is expected to die following a specific period of exposure. The $LC_{50}$ can be expressed in several manners; for example, as parts of material per million parts of air, by volume (ppm), or as milligrams of material per cubic meter of air ($mg/m^3$).

**$LD_{50}$.** Lethal Dose 50%. The estimated single dose at which 50% of the population is expected to die. The $LD_{50}$ dose is usually expressed as milligrams or grams of material per kilogram of animal body weight (mg/kg or g/kg). The material may be administered orally or applied to the skin.

## APPENDIX A--Glossary of Terms and Definitions

**LEL or LFL.** Lower explosive limit or lower flammable limit; the lowest concentration of a vapor or gas (lowest percentage of the substance in air) that will produce a flash or fire when an ignition source (e.g., heat, arc, or flame) is present. At concentrations lower than the LEL, the mixture is too "lean" to burn; also see UEL.

**$m^3$.** Cubic meter; a metric measure of volume, approximately 35.3 cubic feet or 1.3 cubic yards.

**Malignant Tumor.** A tumor that can invade surrounding tissues or metastasize to distant sites resulting in life-threatening consequences.

**Melting Point.** The temperature at which a solid substance changes to a liquid state.

**Metabolism.** The conversion of a chemical from one form to another within the body; also referred to as biotransformation.

**Metabolite.** A chemical produced during metabolism.

**mg/kg.** Milligrams of substance per kilogram of body weight, commonly used as an expression of toxicological dose (e.g., 15 mg/kg).

**$mg/m^3$.** Milligrams per cubic meter; a unit for measuring concentrations of particulates or gases in the air (a weight per unit volume). For example, 20 $mg/m^3$.

**milligram (mg).** The most commonly used unit of measure in medicine and toxicity consisting of one thousandth of a gram ($1x10^{-3}$ g).

**Mixture.** Any combination of two or more substances, if the combination is not, in whole or part, the result of chemical reaction.

**ml.** Milliliter; a metric unit of volume. There are 1,000 milliliters in one liter. 1 teaspoon = 5 milliliters.

**Mutagen.** A substance or agent capable of altering the genetic material in a living cell (mutation).

**NFPA.** The National Fire Protection Association is an international membership organization which promotes fire protection and prevention and establishes safeguards against loss of life and property by fire.

**NIOSH.** The National Institute for Occupational Safety and Health is a part of the Centers for Disease Control and Prevention, U.S. Public Health Service, U.S. Department of Health and Human Services.

**NTP.** The National Toxicology Program is a component of the U.S. Public Health Service. The NTP publishes the *Annual Report on Carcinogens*.

**Odor Threshold.** The lowest concentration of a substance in air that can be detected by smell.

**Oxidation.** A change in a chemical characterized by the loss of electrons. In a literal sense, oxidation is a reaction in which a substance combines with oxygen.

**PEL.** Permissible exposure limit; a legally enforceable occupational exposure limit established by OSHA.

## APPENDIX A--Glossary of Terms and Definitions

**ppm.** Parts per million; the proportion (by volume) of a gas or vapor per million parts of air; also the concentration of a chemical in a liquid or solid form.

**Reactivity.** The tendency of a substance to undergo a chemical change with the release of energy. Undesirable effects (pressure build-up, temperature increase, formation of noxious, toxic or corrosive by-products) may occur because of a reaction to heating, burning, direct contact with other materials or other conditions when in use or in storage.

**Risk.** The probability that an adverse effect will occur.

**Solubility.** The ability of a substance to be dissolved in a solvent. Solubility is expressed according to the solvent (e.g., solubility in water, solubility in acetone, etc.).

**STEL.** Short-Term Exposure Limit (ACGIH terminology); see TLV.

**Synonym.** Another name or names by which a material is known. Methyl alcohol, for example, is also known as methanol or wood alcohol.

**Target Organ.** An organ on which a substance exerts a toxic effect.

**Teratogen.** A substance that can cause physical defects in a developing embryo.

**TLV (Threshold Limit Value**). A term used by ACGIH to express the airborne concentration of material to which nearly all persons car be exposed day after day without adverse effects. ACGIH expresses TLVs in four ways-.
**TLV-TWA:** The allowable Time-Weighted Average concentration for a normal 8-hour workday or 40-hour workweek.

**TLV-STEL:** The Short-Term Exposure Limit, or maximum concentration for a continuous 15-minute exposure period (maximum of four such periods per day, with at least 60 minutes between exposure periods, and provided the daily TLV-TWA is not exceeded).

**TLV-C:** The ceiling exposure limit-the concentration that should not be exceeded even momentarily.

**TLV-Skin.** The skin designation refers to the potential contribution to the overall exposure by the cutaneous route, including mucous membranes and the eye. Exposure can be either by airborne or direct contact with the substance. This designation indicates that appropriate measures should be taken to prevent skin absorption.

**Toxic Substance.** Any substance that can cause injury or illness, or which is suspected of being able to cause injury or illness under some conditions.

**Toxicity.** Inherent capacity to produce injury.

**Toxicology.** The study of the harmful interactions of chemicals on living organisms and biological systems.

## APPENDIX A--Glossary of Terms and Definitions

**Trade Name.** The trademark name or commercial trade name for a material or product.

**TWA.** Time-Weighted Average; the concentration of a material to which a person is exposed, averaged over the total exposure time-generally the total workday (8 to12 hours); also see TLV.

**UEL or UFL.** Upper explosive limit or upper flammable limit; the highest concentration of a vapor or gas (highest percentage of the substance in air) that will produce a flash of fire when an ignition source (e.g., heat, arc, or flame) is present. At higher concentrations, the mixture is too "rich" to burn; also see LEL.

**Unstable.** Tending toward decomposition or other unwanted chemical change during normal handling or storage.

**Vapor density.** The weight of a vapor or gas compared to the weight of an equal volume of air is an expression of the density of the vapor or gas. Materials lighter than air (e.g., acetylene, methane, hydrogen) have vapor densities less than 1.0. Materials heavier than air (e.g., propane, hydrogen sulfide, ethane) have vapor densities greater than 1.0. All vapors and gases will mix with air, but the lighter materials will tend to rise and dissipate (unless confined). Heavier vapors and gases are likely to concentrate in low places along or under floors, in sumps, sewers, manholes, trenches, and ditches where they may create fire or health hazards.

**Vapor pressure.** The pressure exerted by a saturated vapor above its own liquid in a closed container, usually reported on MSDSs in millimeters of mercury (mmHg) at $68^0$ F ($20^0$ C).

**Volatility.** A measure of how quickly a substance changes from liquid or solid form to a gaseous form at ordinary temperatures.

# APPENDIX B

## Information Sources Available to Assist with Hazard Determination

This compilation is not intended to be a complete listing of the many literature sources and computerized data bases that include information on the physical and health hazards of chemical substances.

### I. Primary Literature that Contains Comprehensive Data for Many Industrial Chemicals:

**A Comprehensive Guide to the Hazardous Properties of Chemical Substances, 2nd Edition**. Pradyot Patnaik. Wiley & Sons, New York. 1999.

**Chemical Information Manual, 3rd Edition**. OSHA Publication No. 0881. 1995.

**Clinical Toxicology of Commercial Products**. Gleason, Gosselin, and Hodge. The Williams and Wilkins Co., Baltimore. 1984.

**Cooper's Toxic Exposures Desk Reference with CD-ROM**. Andre R. Cooper, R., editor. CRC Press/Lewis Publishers, Inc., Boca Raton, Florida. 1997.

**Dangerous Properties of Industrial and Consumer Chemicals**. Nicholas P. Cheremisinoff. Marcel Dekker, Inc., New York. 1994.

**Documentation of the Threshold Limit Values and Biological Exposure Indices, 7th Edition**. ACGIH, Cincinnati. 2001.

**DOT 1996 Emergency Response Guidebook**. DOT, Washington, DC. 1996.

**Encyclopedia of Toxicology**. Philip Wexler, Editor. Academic Press, San Diego. 1998.

**Guide to Occupational Exposure Values - 2002**. ACGIH, Cincinnati. 2002

**Handbook of Hazardous Chemical Properties**. Nicholas P. Cheremisinoff. Butterworth-Heinemann. 2000

**Handbook of Hazardous Materials**. Morton Corn. Academic Press, San Diego. 1993.

**Handbook of Highly Toxic Materials Handling and Management**. Stanley S. Grossel and Daniel A. Crowl, Editors. Marcel Dekker, Inc., New York. 1994.

**Handbook of Industrial Toxicology, 3rd Edition**. E.R. Plunkett, Editor. Chemical Publishing Co. Inc., New York. 1987.

**Handbook of Organic Solvent Properties**. Ian Smallwood. Butterworth-Heinemann. 1996

**Handbook of Toxic and Hazardous Chemicals and Carcinogens, 4th Edition**. Marshall Sittig. Noyes Data Corp., Park Ridge, New Jersey. 2001.

**Hawley's Condensed Chemical Dictionary, 14th Edition**. Richard J. Lewis, Editor. Van Nostrand Reinhold, New York. 2001.

**Hazardous Chemicals Desk Reference, 5th Edition**, Richard J. Lewis. Jr. John Wiley & Sons/Van Nostrand Reinhold, New York. 2002.

## APPENDIX B--Information Sources Available to Assist with Hazard Determination

**Hazardous Chemicals Handbook, 2nd Edition.** P. Carson and C J Mumford. Butterworth-Heinemann. 2002.

**Hazardous Materials Handbook**. Richard P. Pohanish and Stanley A. Greene, John Wiley & Sons. 1996.

**Hazardous Materials Response Handbook, 2nd Edition**. National Fire Protection Association. Quincy, Massachusetts. 1992.

**Hazardous Materials Toxicology: Clinical Principles of Environmental Health**. John B. Sullivan and Gary R. Krieger. William and Wilkins, Baltimore. 1992.

**Hazardous Substances Resource Guide**. Richard P. Pohanish and Stanley A. Green, editors. Gale Research Inc., Detroit. 1993

**Patty's Hygiene and Toxicology, 5th Edition**, 13 Volume Set. Eula Bingham, Barbara Cohrssen, and Charles H. Powell. John Wiley & Sons. 2001

**Patty's Industrial Hygiene and Toxicology**, **5th edition.** Robert Harris. John Wiley & Sons, New York. 2000.

**Patty's Toxicology Mini Set Volume Two and Three – Metals.** Eula Bingham and Barbara Cohrssen, editors. John Wiley & Sons. 2001.

**Patty's Toxicology, 8 Volume + Index Set**. Eula Bingham, Barbara Cohrssen, and Charles H. Powell. 2001.

**Sax's Dangerous Properties of Industrial Materials, 10th edition.** 3 volume set. Richard J Lewis. John Wiley & Sons. 2000.

**Sittig's Handbook of Toxic and Hazardous Chemicals and Carcinogens, 4th edition.** 2 Volume Set. Marshall Sittig and Richard P. Pohanish, editors. Noyes Publications. 2002.

**The Chemistry of Explosives**. Jacqueline Akhavan, Springer Verlag. 1998.

**The Comprehensive Handbook of Hazardous Materials**. H.L.A. Sacarello. Lewis Publishers, Inc., Boca Raton, Florida. 1994.

**The Merck Index: An Encyclopedia of Chemicals, Drugs and Biologicals, 13th Edition**. Maryadele J. O'Neil, Ann Smith, Patricia, E. Heckelman, John R. Obenchain, Jo Ann R. Gallipeau , and Mary Ann D'Arecca, editors. Merck Co. 2001.

**The Occupational Environment: Its Evaluation and Control**. Salvatore R. Dinardi, editor. AIHA. 1997.

**Toxicology Desk Reference. The Toxic Exposure and Medical Monitoring Index, 5th edition**. Robert P. Ryan and Claude E. Terry, editors. Taylor & Francis. 1999.

**Toxicology of Industrial Compounds**. Hemut Thomas, Robert Hess and Felix Waechter. Taylor & Francis, London. 1996.

## II. Additional Literature that Contain Specific Data for Many Chemicals:

**2002 TLVs and BEIs**. ACGIH, Cincinnati. 2002.

**Bretherick's Handbook of Reactive Chemicals Hazards: An Indexed Guide to Published Data, 6th Edition.** L. Bretherick, P. L. Urben, and M. Pitt. Butterworth-Heinemann, Boston. 1999. Also on CD-ROM.

**Chemical Reaction Hazards, 2nd Edition.** John Barton and Richard Rogers. Gulf Professional Publishing. 1997

**Chemically Induced Birth Defects, 2nd Edition**. James L. Schardein. Marcel Dekker, Inc., New York. 1993.

**Chemistry of Hazardous Materials**. Eugene Meyer. Prentice-Hall, Inc., Englewood Cliffs, NJ. 1977.

**CRC Handbook of Chemistry and Physics, 83rd Edition**. David R. Lide, editor. CRC Press, Boca Raton, Florida. 2003. Also on CD-ROM.

**Ethel Browning's Toxicity and Metabolism of Industrial Solvents**. Three volumes. Elsevier Science Publishing Co., New York. 1992.

**Explosives Identification Guide**. Mike Pickett and Delmar Learning. 1998.

**Hamilton and Hardy's Industrial Toxicology, 5th Edition**. Raymond D. Harbison. Mosby Inc., St. Louis. 1998.

**Handbook of Physical Properties of Organic Chemicals**. Phillip H. Howard and William M. Meylan, editors. Lewis Publishers, Inc. 1997.

**IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man.** International Agency for Research on Cancer, WHO, Lyon, France. (latest edition)

**Fire Protection Guide to Hazardous Materials, 2001 Edition. NFPA.** National Fire Protection Association, Quincy, MA, USA. 2001.

**NIOSH Pocket Guide to Chemical Hazards**. National Institute for Occupational Safety and Health, U.S. Public Health Service. NIOSH Pub. 94-116. U.S. Government Printing Office, Washington, D.C. 1997.

**NIOSH/OSHA Occupational Health Guidelines for Chemical Hazards**. Original plus 4 supplements. NIOSH/OSHA. 1981-1995.

**NTP's Annual Report on Carcinogens**. National Toxicology Program, Research Triangle Park, NC. (latest edition).

**Reproductively Active Chemicals; A Reference Guide**. Richard J. Lewis. Van Nostrand Reinhold, New York. 1997.

**Wiley Guide to Chemical Incompatibilities, 2nd Edition**. Richard P. Pohanish and Stanley A. Greene. John Wiley & Sons. 2003

**ATSDR's Toxicological Profiles** on CD-ROM, Version 5:1 Cassandra Smith-Simon. US Public Health Service, Atlanta, Georgia, USA. 2003.

## III. Useful Literature for Hazard Communication/Hazard Determination:

**A Guide to OSHA Regulations on Storing and Handling Flammable and Combustible Liquids**. Matthew M. Carmel. 1991.

**ANSI Z400.1 Standard**. American National Standards Institute.

**Chemical Hazard Communication Guidebook, 2nd Edition**. Andrew B. Waldo. McGraw Hill Book Company, Highstown, New Jersey. 1993.

**Chemical Hazards in the Workplace**. Ronald M. Scott. Lewis Publishers, Inc., Chelsea, Michigan. 1989.

**Chemical Safety Manual for Small Business**. American Chemical Society, Washington, D.C.

**Emergency Responder Training Manual for the Hazardous Material Technician**. Center for Labor Education and Research. Van Nostrand Reinhold Co., New York. 1992.

**Emergency Response to Chemical Spills**. W. Brock Neely. Lewis Publishers, Inc., Boca Raton, Florida. 1992.

**Handbook of Chemical Industry Labeling**. Charles J. O'Connor and Sidney I. Lirtzman, editors. Noyes Publications, Park Ridge, New Jersey. 1984.

**Handbook of Hazard Communication and OSHA Requirements**. George G. Lowry and Robert C. Lowry. Lewis Publishers, Inc., Inc., Chelsea, Michigan. 1988.

**Hazard Communication Compliance Manual – A User's Guide to OSHA's Hazard Communication Standard**. J.C. Silk and M.B. Kent, editors. Society for Chemical Hazard Communication. The Bureau of National Affairs, Inc., Washington D.C. 1995.

**Information Resources in Toxicology, 3rd edition**. P.J. Hakkinen, Gerald Kennedy, Frederick Stoss, and Philip Wexler, Editors. Academic Press 1999.

**International Directory of Testing Laboratories**, 1997 Edition. ASTM, West Conshohocken, Pennsylvania. 1997.

**Material Safety Data Sheets. The Writer's Desk Reference**. Richard P. Molinelli, Michael J. Reale, and Ralph I. Freudenthal, editors. Hill and Garnett Publishing, Inc., Boca Raton, Florida, 1992.

**MSDS Pocket Dictionary, 3rd edition**. Genium Publishing. 1998.

**OSHA Technical Manual, 5th edition**. OSHA. 1999.

## IV. General Literature on Toxicology and Industrial Hygiene:

**A Guide to Hazardous Materials Management. Physical Characteristics, Federal Regulations, and Response Alternatives.** Aileen Schumacher. Greenwood Press, Westport, CT. 1988.

**A Textbook of Modern Toxicology, 2nd Edition**. Ernest Hodgson and Patricia E. Levi. McGraw-Hill Professional. 1997.

**Basic Concepts of Industrial Hygiene**. Ronald M. Scott. 1997

**Basic Environmental Toxicology**. Lorris G. Cockerham and Barbara S. Shane. CRC Press, Boca Raton, FL. 1994.

**Basic Toxicology: Fundamentals**, Target Organs, and Risk Assessment, 3rd Edition. Frank C. Lu. Taylor and Francis, Washington DC, 1996.

**Casarett and Doull's Toxicology: The Basic Science of Poisons, 6th Edition**. Louis J. Casarett, Curtis D. Klaasen, and John Doull, editors. McGraw-Hill Professional, New York. 2001.

**Comprehensive Review in Toxicology, 2nd Edition**. Peter D. Bryson. Aspen Publishers, Rockville, Maryland. 1989.

**Comprehensive Toxicology**. I. Glenn Sipes, A. Jay Gaddolfi, and Charlene A. McQueen, Elsevier Science. 1997.

**Dictionary of Chemical Names and Synonyms**. Philip H. Howard and Michael Neal. ACGIH Publication 9422. ACGIH, Cincinnati. 1992.

**Dictionary of Toxicology, 2nd edition**. Ernest Hodgson, Richard Mailman, and Robert Dow. McMillan References, Ltd. London. 1998.

**Dictionary of Toxicology**. Robert A. Lewis, Editor. Lewis Publishers, Inc., Boca Raton, Florida., 1998.

**Emergency Toxicology**. Peter Viccellio, editor. Lippincott-Raven. 1998.

**Environmental and Occupational Medicine, 3rd Edition.** William N. Rom, Editor. Little, Brown and Co., Boston. 1998.

**Essentials of Environmental Toxicology**. W. William Hughes. Taylor and Francis, Washington D.C. 1996.

**Fundamentals of Industrial Hygiene.** Barbara A. Plog and Patricia J. Quinlan, Natl Safety Council. 2001.

**General and Applied Toxicology, 2nd edition**. Bryan Ballantyne, Timothy Marrs and Tore Syverson, editors. McMillan References, Ltd., London. 1999.

**Handbook of Chemical Health and Safety**. Robert Alaimo, editor. 2001.

**Handbook of Toxicology, 2nd Edition**. Michael J Derelanko and Mannfred A Hollinger. CRC Press. 2002.

**Health Protection from Chemicals in the Workplace**. P. Lewis. Englewood Cliffs, Prentice Hall, New Jersey. 1993.

**Industrial Toxicology**. Phillip L. Williams and James L. Burson. Van Nostrand Reinhold, New York. 1989.

**Loomis's Essentials of Toxicology, 4th Edition**. Ted A. Loomis. Academic Press, San Diego, CA: 1996.

**Occupational Health and Safety, 2nd Edition**. Joseph LaDou, editor. National Safety Council, Chicago, Illinois. 1993.

**Occupational Health Guidelines**. NIOSH/OSHA. NIOSH Pub. No. 81-123.

**Occupational Health Risk Assessment and Management**. Blackwell Science, Ltd., Oxford, England. 1999.

**Occupational Medicine, 3rd Edition**. Carl Zenz, O. Bruce Dickerson and Edward P. Horvath, Jr. Mosby - Year Book, Inc., St. Louis. 1994.

**Occupational Toxicology, 2nd edition**. Neill H. Stacey and Chris Winder, editors. Taylor & Francis, Inc., Bristol, Pennsylvania. 2002.

**Principles and Methods of Toxicology, 3rd Edition**. A. Wallace Hayes, Editor. Raven Press, New York. 1994.

**Principles of Toxicology: Environmental and Industrial Applications, 2nd Edition**. Phillip L. Williams and Robert C. James and Stephen M. Roberts, editors. 2000.

**Proctor and Hughes' Chemical Hazards of the Workplace, 4th Edition**. Gloria J. Hathaway, Nick H. Proctor, and James P. Hughes. Van Nostrand Reinhold, New York. 1996.

**Rapid Guide to Hazardous Chemicals in the Workplace, 3rd Edition**. Richard J. Lewis, Sr. Van Nostrand Reinhold. 1994.

**Recognition of Health Hazards in Industry, 2nd Edition**. William A. Burgess. John Wiley and Sons, New York. 1995.

**Toxicology.** Thomas J. Haley and William O. Berndt, Editors. Hemisphere Publishing Corp., New York. 1988.

**Toxicology: A Primer on Toxicology Principles and Applications**. Michael A. Kamrin. Lewis Publishers, Inc., Boca Raton, Florida, Inc., 1988.

## V. Primary Sources of Computerized Information on Occupational Health and Toxicology

### Chemical Profiles/Records (Factual) DataBases

**Canadian Centre for Occupational Health and Safety (CCOHS**). CD-ROMs containing the complete text of more than 80,000 MSDSs on chemical products contributed by over 600 manufacturers and suppliers. http://www.ccohs.ca/

**Chemical Hazard Response Information System (CHRIS).** This database developed by the Coast Guard contains physical and chemical properties and health hazards for over 1,000 chemical substances. Available from Chemical Information Systems.

**ChemID**. This is an on-line data file of the NLM that contains names, synonyms, CAS registry numbers, and a locator for other database that contain information for thousands of chemicals.

**CHEMTREC Hazard Information Transmission**. Chemical profiles represent a synthesis of information from reference materials and MSDS's submitted by industry. The database is for use of groups which respond to chemical emergencies. Operated by the Chemical Manufacturers Association.

**Hazardous Substances Data Bank (HSDB)**. This is peer-reviewed data base which contains chemical and physical properties for over 4200 chemicals. It is available from the NLM.

**KIRK-OTHMER ONLINE**. The online version of the Kirk-Othmer Encyclopedia of Chemical Technology.

**MERCK INDEX**. Full text of the printed edition. Gives concise information on over 10,000 chemicals.

**Registry of Toxic Effects of Chemical Substances (RTECS®).** This is an extensive chemical database published by NIOSH and serves as an important reference for the identification of health hazards. RTECS is available via the NLM MEDLARS.

**Comprehensive Bibliographic DataBases**

**CANCERLIT.** Contains coverage of literature on cancer research and testing from 1963 to the present.

**CHEMID/SUPERLIST**. This file maintained by the NLM serves as a locator for NLM databases containing information for over 180,000 compounds. It also lists chemicals regulated by other Government agencies.

**CIS DATABASE**. Produced by International Occupational Safety and Health Information Center of the International Labour Organization *(ILO),* it indexes worldwide literature on occupational safety and health.

**DART**. A bibliographic database covering teratology and other aspects of developmental and reproductive toxicology. Serves as a continuation of ETIC.

**DERMAL.** Contains toxic effects, absorption, distribution, metabolism, and excretion data related to dermal absorption of 650+ chemicals.

**DIRLINE**. A database containing information about information resource centers, primarily health and biomedical organizations.

**EMIC**. A bibliographic database on chemical agents that have been tested for mutagenic activity.

**ETIC.** A bibliographic database on chemical agents that have been tested for mutagenic activity.

**MEDLINE**. Indexes articles from 3,200+ biomedical journals published in the U.S. and abroad. It is a major source of biomedical literature with coverage from 1966 to the present. Produced by the NLM.

**NIOSHTIC.** This is the NIOSH Technical Information Center file and covers occupational health and safety literature from over 400 journals.

**TERIS**. Produced by the University of Washington and deals with the risks of prenatal exposure to hazardous substances.

**TOXLINE.** Contains comprehensive bibliographic coverage of toxicology information in published literature.

**TSCATS.** Indexes unpublished health and safety studies and test data for over 2700 chemicals submitted to EPA under the Toxic Substances Control Act (TSCA).

## VI. Internet Access Addresses for Information or Publications Related to Chemical Hazards and HazCom:

2000 Emergency Response Guidebook: http://hazmat.dot.gov/gydebook.htm

ACGIH: http://www.acgih.org/

Canadian Centre for Occupational Safety and Health: http://www.ccohs.ca

Center for Environmental and Regulatory Services: http://www.ceris.purdue.edu

EPA Publications: http://www.epa.gov/epahome/publications.htm /

IARC List of Carcinogens: http://monographs.iarc.fr//

MSDSOnline.com (www.msdsonline.com)

MSDSSearch.com. (msdssearch.com)

National Safety council: http://www.nsc.org/

NIOSH Documents: http://www.cdc.gov/niosh/homepage.html

NIOSH Pocket Guide to Chemical Hazards: http://www.cdc.gov/niosh/npg/npg.html

NLM Data Bases: http://sis.nlm.nih.gov/Chem/ChemMain.html

NTP Annual Report of Carcinogens: http://ntp-server.niehs.nih.gov/NewHomeRoc/AboutRoC.html /

OSHA: http://www.osha.gov

Sigma Aldrich MSDSs: http://www.sigmaaldrich.com/

Society for Chemical Hazard Communication: http://www.schc.org.

TOXTUTOR: http://sis.nlm.nih.gov/toxframe.htm

U. Kentucky MSDS Locator: http://www.ilpi.com/msds/index.html

## VII.Trade Associations :

American Chemistry Council (ACC). Arlington, VA. http://www.american chemistry.com.

Synthetic Organic Chemical Manufacturers Association (SOCMA). Washington D.C. http://www.socma.com.

American Petroleum Institute (API), Washington D.C. http://www.api.org.

Chemical Producers and Distributors Association, Alexandria, VA. http://www.cpda.com.

## APPENDIX C

## Materials Regulated by OSHA as Toxic and Hazardous Substances (29 CFR 1910) (Continued)

2,4,5-T
2,4-D (Dichlorylphenoxyacetic acid)
Acetaldehyde
Acetic acid
Acetic anhydride
Acetone
Acetonitrile
Acetylene tetrabromide
Acetylsalicylic acid (Aspirin)
Acrolein
Acrylamide
Acrylic acid
Aldrin
Allyl alcohol
Allyl chloride
Allyl glycidyl ether
Allyl propyl disulfide
alpha-Alumina
Aluminum metal
Aluminum, alkyls
Aluminum, pyro powders
Aluminum, soluble salts
Aluminum, welding fumes
2-Aminopyridine
Amitrole
Ammonia
Ammonium chloride fume
Ammonium sulfamate
sec-Amyl acetate
n-Amyl acetate
Aniline and homologs
Anisidine (o-, p- isomers)
Antimony
Antimony compounds
ANTU (alpha-Naphthyl thiourea)
Arsenic
Arsine
Atrazine
Azinphos-methyl
Barium
Barium sulfate
Barium, soluble compounds
Benomyl
Benzene
Benzoyl peroxide
Benzyl chloride
Beryllium
Beryllium compounds, n.o.s.
Bismuth telluride (Se doped)
Bismuth telluride, undoped
Borates, tetra, sodium salts, anhydrous
Borates, tetra, sodium salts, decahydrate
Borates, tetra, sodium salts, pentahydrate
Boron oxide
Boron tribromide
Boron trifluoride
Bromacil
Bromine
Bromine pentafluoride
Bromoform
Butadiene (1,3-Butadiene)
Butane
2-Butanone (Methyl ethyl ketone)
2-Butoxyethanol
n-Butyl acetate
tert-Butyl acetate
sec-Butyl acetate
Butyl acrylate
tert-Butyl alcohol
sec-Butyl alcohol
n-Butyl alcohol
tert-Butyl chromate
n-Butyl glycidyl ether (BGE)
n-Butyl lactate
Butyl mercaptan
Butylamine (n-)
o-sec-Butylphenol
p-tert-Butyltoluene
Cadmium
Cadmium fume
Calcium carbonate
Calcium cyanamide
Calcium hydroxide
Calcium oxide
Calcium silicate
Calcium sulfate
Camphor, synthetic
Caprolactam
Captafol (Difolatan)
Captan
Carbaryl (Sevin)
Carbofuran (Furadan)
Carbon black
Carbon dioxide
Carbon disulfide
Carbon monoxide
Carbon tetrabromide
Carbon tetrachloride
Carbonyl fluoride
Catechol (pyrocatechol)
Cellulose
Cesium hydroxide
Chlordane
Chlorinated camphene
Chlorinated diphenyl oxide
Chlorine

## APPENDIX C

## Materials Regulated by OSHA as Toxic and Hazardous Substances (29 CFR 1910) (Continued)

Chlorine dioxide
Chlorine trifluoride
1-Chloro-1-nitropropane
2-Chloro-6-(trichloromethyl)pyridine
Chloroacetaldehyde
alpha-Chloroacetophenone (Phenacyl chloride)
Chloroacetyl chloride
Chlorobenzene
o-Chlorobenzylidene malonitrile
Chlorobromomethane
Chlorodifluoromethane
Chlorodiphenyl (42% chlorine) (PCB)
Chlorodiphenyl (54% chlorine) (PCB)
Chloroform (Trichloromethane)
Chloropentafluoroethane
Chloropicrin
Chloropicrin/methyl chloride
beta-Chloroprene
o-Chlorostyrene
o-Chlorotoluene
Chlorpyrifos
Chromates
Chromic acid
Chromium
Chromium (III) compounds, soluble
Chromium insoluble salts
Clopidol
Coal dust (greater than or equal to 5% SiO2), respirable quartz fraction
Coal tar pitch volatiles
Cobalt carbonyl
Cobalt hydrocarbonyl
Cobalt metal, dust and fume
Copper
Copper dusts and mists
Cotton dust (raw)
Crag herbicide (Sesone)
Cresol, all isomers
Crotonaldehyde
Crotonaldehyde, (E)-
Crufomate
Cumene
Cyanamide
Cyanides
Cyanogen
Cyanogen chloride
Cyclohexane
Cyclohexanol
Cyclohexanone
Cyclohexene
Cyclohexylamine
Cyclonite
Cyclopentadiene
Cyclopentane
Cyhexatin
Decaborane
Demeton (Systox)
Di-sec octyl phthalate (Di-2-ethylhexyl-phthalate)
2,6-Di-tert-butyl-p-cresol
Diacetone alcohol (4-Hydroxy-4-methyl-2-pentanone)
Diazinon
Diazomethane
Diborane
Dibutyl phosphate
Dibutyl phthalate
2-N-Dibutylaminoethanol
Dichloro diphenyl trichloroethane (DDT)
1,1-Dichloro-1-nitroethane
1,3-Dichloro-5,5-dimethyl hydantoin
Dichloroacetylene
o-Dichlorobenzene
p-Dichlorobenzene
Dichlorodifluoromethane
1,1-Dichloroethane
Dichloroethyl ether
1,2-Dichloroethylene
Dichlorofluoromethane
1,3-Dichloropropene
2,2-Dichloropropionic acid
1,2-Dichlorotetrafluoroethane
Dichlorvos (DDVP)
Dicrotophos
Dicyclopentadiene
Dicyclopentadienyl iron
Dieldrin
Diethanolamine
Diethyl ketone
Diethyl phthalate
Diethylamine
2-Diethylaminoethanol
Diethylene triamine
Difluorodibromomethane
Diglycidyl ether (DGE)
Diisobutylketone
Diisopropylamine
Dimethyl 1,2-dibromo-2,2-dichloroethyl phosphate
Dimethyl acetamide
Dimethyl aniline (N,N-dimethylaniline)
1,1-Dimethyl hydrazine
Dimethyl phthalate
Dimethyl sulfate
Dimethylamine
Dimethylformamide
Dinitolmide (3,5-Dinitro-o-toluamide)
Dinitro-o-cresol
Dinitrobenzene (alpha-)

## APPENDIX C

## Materials Regulated by OSHA as Toxic and Hazardous Substances (29 CFR 1910) (Continued)

Dinitrobenzene (meta-)
Dinitrobenzene (para-)
Dinitrobenzene, all isomers
Dinitrotoluene
Dioxane (Diethylene dioxide)
Dioxathion (Delnav)
Diphenyl (Biphenyl)
Diphenylamine
Dipropyl ketone
Dipropylene glycol, methyl ether
Diquat
Disulfiram
Disulfoton
Diuron
Divinyl benzene
Emery
Endosulfan
Endrin
Epichlorohydrin
EPN
Ethanolamine
Ethion
2-Ethoxyethanol
2-Ethoxyethyl acetate (Cellosolve acetate)
Ethyl acrylate
Ethyl alcohol (Ethanol)
Ethyl amyl ketone (5-Methyl-3-heptanone)
Ethyl benzene
Ethyl bromide
Ethyl butyl ketone (3-Heptanone)
Ethyl chloride
Ethyl ether
Ethyl formate
Ethyl mercaptan
Ethyl silicate
Ethylacetate
Ethylamine
Ethylene chlorohydrin
Ethylene diamine
Ethylene dibromide (1,2-Dibromoethane)
Ethylene dichloride
Ethylene glycol
Ethylene glycol, dinitrate
Ethylidene norbornene
N-Ethylmorpholine
Fenaminphos
Fensulfothion (Dasanit)
Fenthion
Ferbam
Ferrovanadium dust
Fluorides
Fluorine
Fluorotrichloromethane (Trichlorofluoromethane)
Fonofos
Formaldehyde
Formamide
Formic acid
Furfural
Furfuryl alcohol
Gasoline
Germanium tetrahydride
Glutaraldehyde
Glycerin mist
Glycidol
Grain dust (oat, wheat, barley)
Graphite, natural
Graphite, synthetic
Gypsum
Hafnium
Heptachlor
Heptane (n-Heptane)
Hexachlorobutadiene
Hexachlorocyclo-pentadiene
Hexachloroethane
Hexachloronaphthalene
Hexafluoroacetone
n-Hexane
Hexane isomers
2-Hexanone (Methyl n-butyl ketone)
Hexone (Methyl isobutyl ketone)
sec-Hexyl acetate
Hexylene glycol
Hydrazine
Hydrogen bromide
Hydrogen chloride
Hydrogen cyanide
Hydrogen fluoride
Hydrogen peroxide
Hydrogen selenide
Hydrogen sulfide
Hydrogenated terphenyls
Hydroquinone
2-Hydroxypropyl acrylate
Indene
Indium
Indium compounds, n.o.s.
Iodine
Iodoform
Iron oxide fume
Iron salts (soluble)
Iron, pentacarbonyl-
Isoamyl acetate
Isoamyl alcohol (primary and secondary)
Isobutyl acetate
Isobutyl alcohol
Isooctyl alcohol

## APPENDIX C

## Materials Regulated by OSHA as Toxic and Hazardous Substances (29 CFR 1910) (Continued)

Isophorone
Isophoronediisocyanate
2-Isopropoxyethanol
Isopropyl acetate
Isopropyl alcohol
Isopropyl ether
Isopropyl glycidyl ether (IGE)
Isopropylamine
N-Isopropylaniline
Kaolin
Ketene
L.P.G. (liquified petroleum gas)
Lindane
Lithium hydride
Magnesite
Magnesium oxide fume
Malathion
Maleic anhydride
Manganese
Manganese cyclopentadienyl tricarbonyl
Manganese fume
Manganese tetroxide
Mercury
Mercury (organo) alkyl compounds
Mesityl oxide
Methacrylic acid
Methomyl (Lannate)
Methoxychlor
4-Methoxyphenol
Methyl 2-cyanoacrylate
Methyl acetate
Methyl acetylene (Propyne)
Methyl acetylene - Propadiene mixture (MAPP)
Methyl acrylate
Methyl acrylonitrile
Methyl alcohol
Methyl bromide (Bromomethane)
Methyl cellosolve (2-methoxyethanol)
Methyl cellosolve acetate (2-Methoxyethyl acetate)
Methyl chloride
Methyl chloroform (1,1,1-Trichloroethane)
Methyl cyclopentadienyl manganese tricarbonyl
Methyl demeton
Methyl ethyl ketone peroxide (MEKP)
Methyl formate
Methyl hydrazine (Monomethyl hydrazine)
Methyl iodide
Methyl isoamyl ketone
Methyl isocyanate
Methyl isopropyl ketone
Methyl methacrylate
Methyl n-amyl ketone
Methyl parathion
Methyl silicate
alpha-Methyl styrene
Methylal (Dimethoxymethane)
Methylamine
Methylcyclohexane
Methylcyclohexanol
o-Methylcyclohexanone
Methylene bis(4-cyclohexylisocyanate)
Methylene bisphenol isocyanate (MDI)
Methylene chloride
4,4'-Methylenebis(2-chloroaniline) (MBOCA)
Methylisobutyl carbinol
Methylmercaptan
Metribuzin
Mica
Molybdenum
Molybdenum insoluble compounds
Molybdenum soluble compounds
Monocrotophos (Azodrin)
Monomethylaniline
Morpholine
Naphtha (coal tar)
Naphthalene
Nickel
Nickel carbonyl
Nickel insoluble compounds
Nickel soluble compounds
Nicotine
Nitric acid
Nitric oxide
p-Nitroaniline
Nitrobenzene
p-Nitrochlorobenzene
Nitroethane
Nitrogen dioxide
Nitrogen trifluoride
Nitroglycerin
Nitromethane
2-Nitropropane
1-Nitropropane
o-Nitrotoluene
m-Nitrotoluene
p-Nitrotoluene
Nonane
Octachloronaphthalene
Octane
Oil mist, mineral
Osmium tetroxide
Oxalic acid
Oxygen difluoride
Ozone
Paraffin wax fume
Paraquat

## APPENDIX C

## Materials Regulated by OSHA as Toxic and Hazardous Substances (29 CFR 1910) (Continued)

Paraquat
Paraquat methosulfate
Parathion
Particulates not otherwise regulated
Pentaborane
Pentachloronaphthalene
Pentachlorophenol
Pentaerythritol
Pentane
2-Pentanone (Methyl propyl ketone)
Perchloroethylene (Tetrachloroethylene)
Perchloryl fluoride
Perlite
Petroleum distillates (naphtha) (rubber solvent)
Phenol
Phenothiazine
Phenyl ether
Phenyl ether-Biphenyl mixture vapor
Phenyl glycidyl ether (PGE)
Phenyl mercaptan
p-Phenylene diamine
Phenylhydrazine
Phenylphosphine
Phorate
Phosdrin (Mevinphos)
Phosgene (Carbonyl chloride)
Phosphine
Phosphoric acid
Phosphorus (yellow)
Phosphorus oxychloride
Phosphorus pentachloride
Phosphorus pentasulfide
Phosphorus trichloride
Phthalic anhydride
m-Phthalodinitrile
Picloram
Picric acid
Pindone (2-pivalyl-1,3-indandione)
Piperazine dihydrochloride
Plaster of paris
Platinum
Platinum soluble salts
Portland cement
Potassium hydroxide
Propane
Propargyl alcohol
Propionic acid
Propoxur (Baygon)
n-Propyl acetate
n-Propyl alcohol
n-Propyl nitrate
Propylene dichloride
Propylene glycol dinitrate
Propylene glycol monomethyl ether
Propylene imine
Propylene oxide
Pyrethrum
Pyridine
Quinone
Resorcinol
Rhodium
Rhodium soluble compounds
Rhodium, insoluble compounds
Ronnel
Rosin core solder pyrolysis products, as formaldehyde
Rotenone
Rouge
Selenium
Selenium compounds
Selenium hexafluoride
Silica, amorphous, diatomaceous earth, containing less than1% crystalline silica
Silica, amorphous, precipitated and gel
Silica, crystalline, tridymite
Silica, fused
Silica-crystalline, cristobalite
Silica-crystalline, quartz
Silica-crystalline, tripoli
Silicon
Silicon carbide
Silicon tetrahydride
Silver soluble compounds
Silver, metal
Soapstone
Sodium azide
Sodium bisulfite
Sodium fluoroacetate
Sodium hydroxide
Sodium metabisulfite
Starch
Stibine
Stoddard solvent
Strychnine
Styrene
Subtilisins (proteolytic enzymes)
Sucrose
Sulfur dioxide
Sulfur hexafluoride
Sulfur monochloride
Sulfur pentafluoride
Sulfur tetrafluoride
Sulfuric acid
Sulfuryl fluoride
Sulprofos
Talc (containing no asbestos)
Tantalum metal

## APPENDIX C

## Materials Regulated by OSHA as Toxic and Hazardous Substances (29 CFR 1910) (Continued)

Tantalum, oxide dusts
TEDP (Sulfotep)
Tellurium
Tellurium compounds, n.o.s.
Tellurium hexafluoride
Temephos
TEPP
Terphenyls
1,1,2,2-Tetrachloro-1,2-difluoroethane
1,1,1,2-Tetrachloro-2,2-difluoroethane
1,1,2,2-Tetrachloroethane
Tetrachloronaphthalene
Tetraethyllead
Tetrahydrofuran
Tetramethyl lead
Tetramethyl succinonitrile
Tetranitromethane
Tetrasodium pyrophosphate
Tetryl (2,4,6-Trinitro-phenylmethylnitramine)
Thallium soluble compounds
Thallium soluble compounds
4,4'-Thiobis(6-tert-butyl-m-cresol)
Thioglycolic acid
Thionyl chloride
Thiram
Tin
Tin inorganic compounds
Tin organic compounds
Tin oxide
Titanium dioxide
Toluene
Toluene 2,4-diisocyanate (TDI)
p-Toluidine
o-Toluidine
m-Toluidine
Tributyl phosphate
1,1,2-Trichloro-1,2,2-trifluoroethane
Trichloroacetic acid
1,2,4-Trichlorobenzene
1,1,2-Trichloroethane
Trichloroethylene
Trichloromethanesulphenyl chloride
Trichloronaphthalene
1,2,3-Trichloropropane
Triethylamine
Trifluorobromomethane
Trimellitic anhydride
Trimethyl benzene
Trimethyl phosphite
Trimethylamine
2,4,6-Trinitrotoluene (TNT)
Triorthocresyl phosphate
Triphenyl amine
Triphenyl phosphate
Tungsten
Tungsten, insoluble compounds
Tungsten, soluble compounds
Turpentine
Uranium
Uranium insoluble compounds
Uranium soluble compounds
n-Valeraldehyde
Vanadium
Vegetable oil mist
Vinyl acetate
Vinyl bromide
Vinyl cyclohexene dioxide
Vinyl toluene
Vinylidene chloride (1,1-Dichloroethylene)
VM&P Naphtha
Warfarin
Welding fumes (total particulate)
Wood dust, all soft and hard woods, except western red cedar
Wood dust, western red cedar
m-Xylene-alpha, alpha'-diamine
Xylenes (o-, m-, p- isomers)
Xylidine
Yttrium
Zinc chloride fume
Zinc chromate
Zinc oxide
Zinc stearate
Zirconium
Zirconium compounds, n.o.s.

29CFR1910, Subpart Z-Toxic and Hazardous Substances. Occupational Safety and Health Administration. This list may be updated periodically so that the most current list should be consulted.

## APPENDIX D--OSHA Designated Carcinogens

| Chemical Name |
|---|
| 2-Acetylaminofluorene |
| Acrylonitrile |
| 4-Aminodiphenyl |
| Asbestos |
| Benzene |
| Benzidine |
| 1,3-Butadiene |
| Cadmium |
| bis-Chloromethyl ether |
| Coke oven emissions |
| 1,2-Dibromo-3-chloropropane |
| 3,3'-Dichlorobenzidine (and its salts) |
| 4-Dimethylaminoazobenzene |
| Ethyleneimine |
| Ethylene oxide |
| Formaldehyde |
| Inorganic arsenic |
| Methyl chloromethyl ether |
| Methylene chloride |
| Methylenedianiline |
| alpha-Naphthylamine |
| beta-Naphthylamine |
| 4-Nitrobiphenyl |
| N-Nitrosodimethylamine |
| beta-Propiolactone |
| Vinyl chloride |

29 CFR1910, Subpart Z-Toxic and Hazardous Substances. Occupational Safety and Health Administration.

## APPENDIX E--NTP Designated Carcinogens (Continued)

**Part A. Known to be a Human Carcinogen.**

Aflatoxins
Alcoholic Beverage Consumption
4-Aminobiphenyl
Analgesic Mixtures Containing Phenacetin
Arsenic Compounds, Inorganic
Asbestos
Azathioprine
Benzene
Benzidine
Beryllium and Beryllium Compounds
1,3-Butadiene
1,4-Butanediol Dimethylsulfonate (Myleran ®)
Cadmium and Cadmium Compounds
Chlorambucil
1-(2-Chloroethyl)-3-(4-methylcyclohexyl)-1-nitrosourea (MeCCNU)
bis(Chloromethyl) Ether and Technical-Grade Chloromethyl Methyl Ether
Chromium Hexavalent Compounds
Coal Tar Pitches
Coal Tars
Coke Oven Emissions
Cyclophosphamide
Cyclosporin A (Ciclosporin)
Diethylstilbestrol
Dyes Metabolized to Benzidine
Environmental Tobacco Smoke
Erionite
Estrogens, Steroidal
Ethylene Oxide
Melphalan
Methoxsalen with Ultraviolet A Therapy (PUVA)
Mineral Oils (Untreated and Mildly Treated)
Mustard Gas
2-Naphthylamine
Nickel Compounds
Radon
Silica, Crystalline (Respirable Size)
Smokeless Tobacco
Solar Radiation
Soots
Strong Inorganic Acid Mists Containing Sulfuric Acid
Sunlamps or Sunbeds, Exposure to
Tamoxifen 22
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD); "Dioxin"
Thiotepa
Thorium Dioxide
Tobacco Smoking
Vinyl Chloride
Ultraviolet Radiation, Broad Spectrum UV Radiation
Wood Dust

**Part B. Reasonably Anticipated to be a Human Carcinogen.**

Acetaldehyde
2-Acetylaminofluorene
Acrylamide
Acrylonitrile
Adriamycin ® (Doxorubicin Hydrochloride)
2-Aminoanthraquinone
o-Aminoazotoluene
1-Amino-2-methylanthraquinone
2-Amino-3-methylimidazo[4,5-f]quinoline (IQ)
Amitrole
o-Anisidine Hydrochloride
Azacitidine (5-Azacytidine ® , 5-AzaC)
Benz[a]anthracene
Benzo[b]fluoranthene
Benzo[j]fluoranthene
Benzo[k]fluoranthene
Benzo[a]pyrene
Benzotrichloride
Bromodichloromethane
2,2-bis-(Bromoethyl)-1,3-propanediol (Technical Grade)
Butylated Hydroxyanisole (BHA)
Carbon Tetrachloride
Ceramic Fibers (Respirable Size)
Chloramphenicol
Chlorendic Acid
Chlorinated Paraffins (C12, 60% Chlorine)
1-(2-Chloroethyl)-3-cyclohexyl-1-nitrosourea
bis(Chloroethyl) nitrosourea
Chloroform
3-Chloro-2-methylpropene
4-Chloro-o-phenylenediamine
Chloroprene
p-Chloro-o-toluidine and p-Chloro-o-toluidine Hydrochloride (See p-Chloro-o-toluidine and p-Chloro-o-toluidine Hydrochloride)
Chlorozotocin
C.I. Basic Red 9 Monohydrochloride
Cisplatin
p-Cresidine
Cupferron
Dacarbazine
Danthron (1,8-Dihydroxyanthraquinone)
2,4-Diaminoanisole Sulfate
2,4-Diaminotoluene
Dibenz[*a,*h]acridine (See Polycyclic Aromatic Hydrocarbons)
Dibenz[*a,*j]acridine (See Polycyclic Aromatic Hydrocarbons)
Dibenz[*a,*h]anthracene (See Polycyclic Aromatic Hydrocarbons)

## APPENDIX E--NTP Designated Carcinogens (Continued)

7H-Dibenzo[*c*,g]carbazole (See Polycyclic Aromatic Hydrocarbons)
Dibenzo[*a*,e]pyrene
Dibenzo[*a*,h]pyrene
Dibenzo[*a*,i]pyrene
Dibenzo[*a*,l]pyrene
1,2-Dibromo-3-chloropropane
1,2-Dibromoethane (Ethylene Dibromide)
2,3-Dibromo--propanol
tris(2,3-Dibromopropyl) Phosphate
1,4-Dichlorobenzene
3,3'-Dichlorobenzidine and 3,3'-Dichlorobenzidine Dihydrochloride
Dichlorodiphenyltrichloroethane (DDT)
1,2-Dichloroethane (Ethylene Dichloride)
Dichloromethane (Methylene Chloride)
1,3-Dichloropropene (Technical Grade)
Diepoxybutane
Diesel Exhaust Particulates
Diethyl Sulfate
Diglycidyl Resorcinol Ether
3,3'-Dimethoxybenzidine
4-Dimethylaminoazobenzene
3,3'-Dimethylbenzidine
Dimethylcarbamoyl Chloride
1,1-Dimethylhydrazine
Dimethyl Sulfate
Dimethylvinyl Chloride
1,6-Dinitropyrene
1,8-Dinitropyrene
1,4-Dioxane
Disperse Blue
Dyes Metabolized to 3,3'-Dimethoxybenzidine
Dyes Metabolized to 3,3'-Dimethylbenzidine
Epichlorohydrin
Ethylene Thiourea
di(2-Ethylhexyl) Phthalate
Ethyl Methanesulfonate
Formaldehyde (Gas)
Furan
Glasswool (Respirable Size)
Glycidol
Hexachlorobenzene
Hexachlorocyclohexane Isomoers
Hexachloroethane
Hexamethylphosphoramide
Hydrazine and Hydrazine Sulfate
Hydrazobenzene
Indeno[1,2,3-*cd*]pyrene
Iron Dextran Complex
Isoprene
Kepone ® (Chlordecone)
Lead Acetate (See Lead Acetate and Lead Phosphate)
Lead Phosphate (See Lead Acetate and Lead Phosphate)
Lindane and Other Hexachlorocyclohexane Isomers
2-Methylaziridine (Propylenimine)
5-Methylchrysene (See Polycyclic Aromatic Hydrocarbons)
4,4'-Methylenebis(2-chloroaniline)
4-4'-Methylenebis(*N*,N-dimethyl)benzenamine
4,4'-Methylenedianiline and 4,4'-Methylenedianiline Dihydrochloride
Methyleugenol
Methyl Methanesulfonate
N-Methyl-N'-nitro-N-nitrosoguanidine
Metronidazole
Michler's Ketone [4,4'-(Dimethylamino)benzophenone]
Mirex
Nickel (Metallic)
Nitrilotriacetic Acid
o-Nitroanisole
6-Nitrochrysene
Nitrofen (2,4-Dichlorophenyl-p-nitrophenyl ether)
Nitrogen Mustard Hydrochloride
2-Nitropropane
1-Nitropyrene
4-Nitropyrene
N-Nitrosodi-n-butylamine
N-Nitrosodiethanolamine
N-Nitrosodiethylamine
N-Nitrosodimethylamine
N-Nitrosodi-n-propylamine
N-Nitroso-N-ethylurea
4-(N-Nitrosomethylamino)-1-(3-pyridyl)-1-butanone
N-Nitroso-N-methylurea
N-Nitrosomethylvinylamine
N-Nitrosomorpholine
N-Nitrosonornicotine
N-Nitrosopiperidine
N-Nitrosopyrrolidine
N-Nitrososarcosine
Norethisterone
Ochratoxin A
4,4'-Oxydianiline
Oxymetholone
Phenacetin
Phenazopyridine Hydrochloride
Phenolphthalein
Phenoxybenzamine Hydrochloride
Phenytoin
Polybrominated Biphenyls (PBBs)
Polychlorinated Biphenyls (PCBs)
Polycyclic Aromatic Hydrocarbons (PAHs)
Procarbazine Hydrochloride
Progesterone
1,3-Propane Sultone

## APPENDIX E--NTP Designated Carcinogens (Continued)

β-Propiolactone
Propylene Oxide
Propylthiouracil
Reserpine
Safrole
Selenium Sulfide
Streptozotocin
Styrene-7,8-oxide
Sulfallate
Tetrachloroethylene (Perchloroethylene)
Tetrafluoroethylene
Tetranitromethane
Thioacetamide
Thiourea
Toluene Diisocyanate
o-Toluidine and o-Toluidine Hydrochloride
Toxaphene
Trichloroethylene
2,4,6-Trichlorophenol
1,2,3-Trichloropropane
Ultraviolet A Radiation
Ultraviolet B Radiation
Ultraviolet C Radiation
Urethane
Vinyl Bromide
4-Vinyl-1-cyclohexene Diepoxide
Vinyl Fluoride

β-Propiolactone
Propylene Oxide
Propylthiouracil
Reserpine
Safrole
Selenium Sulfide
Streptozotocin
Styrene-7,8-oxide
Sulfallate
Tetrachloroethylene (Perchloroethylene)
Tetrafluoroethylene
Tetranitromethane
Thioacetamide
Thiourea
Toluene Diisocyanate
o-Toluidine and o-Toluidine Hydrochloride
Toxaphene
Trichloroethylene
2,4,6-Trichlorophenol
1,2,3-Trichloropropane
Ultraviolet A Radiation
Ultraviolet B Radiation
Ultraviolet C Radiation
Urethane
Vinyl Bromide
4-Vinyl-1-cyclohexene Diepoxide
Vinyl Fluoride

*Agents, Substances, Mixtures or Exposure Circumstances Known to be Human Carcinogens.* 10th Report on Carcinogens, January 2003. U.S. Department of Health and Human Services, Public Health Service, National Toxicology Program.

## APPENDIX F

## IARC Designated Carcinogens (Continued)

**Group 1: Carcinogenic to humans**

**Agents and groups of agents**

Aflatoxins (naturally occurring mixtures of)
4-Aminobiphenyl
Arsenic and arsenic compounds
Asbestos
Azathioprine
Benzene
Benzidine
Beryllium and beryllium compounds
*N*,*N*-Bis(2-chloroethyl)-2-naphthylamine (Chlornaphazine)
Bis(chloromethyl)ether and chloromethyl methyl ether (technical-grade)
1,4-Butanediol dimethanesulfonate (Busulphan; Myleran)
Cadmium and cadmium compounds
Chlorambucil
1-(2-Chloroethyl)-3-(4-methylcyclohexyl)-1-nitrosourea (Methyl-CCNU;Semustine)
Chromium[VI] compounds
Ciclosporin
Cyclophosphamide
Diethylstilboestrol
Epstein-Barr virus
Erionite
Ethylene oxide
Etoposide in combination with cisplatin and bleomycin
[Gamma Radiation: see X- and Gamma ($\gamma$)-Radiation]
*Helicobacter pylori* (infection with)
Hepatitis B virus (chronic infection with)
Hepatitis C virus (chronic infection with)
Herbal remedies containing plant species of the genus *Aristolochia*
Human immunodeficiency virus type 1 (infection with)
Human papillomavirus type 16
Human papillomavirus type 18
Human T-cell lymphotropic virus type I
Melphalan
8-Methoxypsoralen (Methoxsalen) plus ultraviolet Aradiation
MOPP and other combined chemotherapy including alkylating agents
Mustard gas (Sulfur mustard)
2-Naphthylamine
Neutrons
Nickel compounds
Oestrogen therapy, postmenopausal
Oestrogens, nonsteroidal)
Oestrogens, steroidal
*Opisthorchis viverrini* (infection with)
Oral contraceptives, combined
Oral contraceptives, sequential
Phosphorus-32, as phosphate
Plutonium-239 and its decay products (may contain plutonium-240 and other isotopes)
Radioiodines, short-lived isotopes, including iodine-131, from atomic reactor accidents and nuclear weapons detonation (exposure during childhood)
Radionuclides, $\alpha$-particle-emitting, internally deposited
Radionuclides, $\beta$-particle-emitting, internally deposited
Radium-224 and its decay products
Radium-226 and its decay products
Radium-228 and its decay products
Radon-222 [10043-92-2] and its decay products
*Schistosoma haematobium* (infection with)
Silica, crystalline (inhaled in the form of quartzor cristobalite from occupational sources)
Solar radiation
Talc containing asbestiform fibres
Tamoxifen
2,3,7,8-Tetrachlorodibenzo-*para*-dioxin
Thiotepa
Thorium-232 and its decay products, administered intravenously as a colloidal dispersion of thorium-232 dioxide
Treosulfan
Vinyl chloride
X- and Gamma ($\gamma$)-Radiation

**Mixtures**

Alcoholic beverages

## APPENDIX F

## IARC Designated Carcinogens (Continued)

Analgesic mixtures containing phenacetin
Betel quid with tobacco
Coal-tar pitches
Coal-tars
Mineral oils, untreated and mildly treated
Salted fish (Chinese-style)
Shale-oils
Soots
Tobacco products, smokeless
Tobacco smoke
Wood dust

**Exposure circumstances**

Aluminium production
Auramine, manufacture of
Boot and shoe manufacture and repair
Coal gasification
Coke production
Furniture and cabinet making
Haematite mining (underground) with exposure to radon
Iron and steel founding
Isopropanol manufacture (strong-acid process)
Magenta, manufacture of
Painter (occupational exposure as a)
Rubber industry
Strong-inorganic-acid mists containing sulfuric acid (occupationalexposure to)

**Group 2A: Probably carcinogenic to humans**

**Agents and groups of agents**

Acrylamide
Adriamycin
Androgenic (anabolic) steroids
Aristolochic acids (naturally occurring mixtures of)
Azacitidine
Benz[*a*]anthracene
Benzidine-based dyes
Benzo[*a*]pyrene
Bischloroethyl nitrosourea (BCNU)
1,3-Butadiene
Captafol
Chloramphenicol
$\alpha$-Chlorinated toluenes (benzal chloride, benzotrichloride, benzyl chloride and benzoyl chloride (combined exposures)
1-(2-Chloroethyl)-3-cyclohexyl-1-nitrosourea (CCNU)
4-Chloro-*ortho*-toluidine
Chlorozotocin
Cisplatin
*Clonorchis sinensis* (infection with)
Dibenz[*a,h*]anthracene
Diethyl sulfate
Dimethylcarbamoyl chloride
1,2-Dimethylhydrazine
Dimethyl sulfate
Epichlorohydrin
Ethylene dibromide
*N*-Ethyl-*N*-nitrosourea
Etoposide
Formaldehyde
Glycidol
Human papillomavirus type 31
Human papillomavirus type 33
IQ (2-Amino-3-methylimidazo[4,5-*f*]quinoline)
Kaposi's sarcoma herpesvirus/human herpesvirus 8
5-Methoxypsoralen
4,4´-Methylene bis(2-chloroaniline) (MOCA)
Methyl methanesulfonate
*N*-Methyl-*N´*-nitro-*N*-nitrosoguanidine(MNNG)
*N*-Methyl-*N*-nitrosourea
Nitrogen mustard
*N*-Nitrosodiethylamine
*N*-Nitrosodimethylamine
Phenacetin
Procarbazine hydrochloride
Styrene-7,8-oxide
Teniposide
Tetrachloroethylene
*ortho*-Toluidine
Trichloroethylene
1,2,3-Trichloropropane
Tris(2,3-dibromopropyl) phosphate

## APPENDIX F

## IARC Designated Carcinogens (Continued)

Ultraviolet radiation A
Ultraviolet radiation B
Ultraviolet radiation C
Vinyl bromide
Vinyl fluoride

**Mixtures**

Creosotes (from coal-tars)
Diesel engine exhaust
Hot mate
Non-arsenical insecticides (occupational exposures in spraying and application of)
Polychlorinated biphenyls

Last updated: 4 December 2002